YEAR BOOK

OF THE

American Iron and Steel Institute

1922

MAY MEETING - - - - - - - NEW YORK
OCTOBER MEETING - - - - - NEW YORK

Published by the
AMERICAN IRON AND STEEL INSTITUTE
40 Rector Street, New York

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WYNKOOP HALLENBECK CRAWFORD COMPANY
NEW YORK, N. Y.

PREFACE

This book constitutes the twelfth volume of the series containing the proceedings of the General Meetings of the American Iron and Steel Institute. The first volume, containing the proceedings of the First General Meeting held in New York on Friday, October 14, 1910, and continued in Buffalo, Chicago, Pittsburgh and Washington, was published under the title "Proceedings of the American Iron and Steel Institute." In 1911, no General Meetings were held. In 1912 and subsequently two General Meetings have been held each year with the single exception of the year 1918, the October Meeting of that year being omitted because of war activities. In 1912 the proceedings were first published under the title "Year Book of the American Iron and Steel Institute," and this title has been continued in subsequent volumes.

The present volume contains the proceedings of the Twenty-first General Meeting held at the Hotel Commodore, New York, May 26, 1922, and the proceedings of the Twenty-second General Meeting, held at the Hotel Commodore, New York, October 27, 1922.

Howard H. Cook,
Assistant Secretary.

77088

TABLE OF CONTENTS

May Meeting

TABLE OF CONTENTS

October Meeting

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AMERICAN IRON AND STEEL INSTITUTE

TWENTY-FIRST GENERAL MEETING

NEW YORK, MAY 26, 1922

The Twenty-first General Meeting of the American Iron and Steel Institute was held at the Hotel Commodore, New York City, on Friday, May 26, 1922.

Following the usual custom, three sessions were held. In order to provide sufficient accommodations for the large number present, the morning session was held in the Grand Ballroom. The afternoon session was held in the East Ballroom. The evening session, which included the semi-annual dinner, was held in the Grand Ballroom. The sessions were devoted to the reading and discussion of papers dealing chiefly with problems of metallurgy and business.

On the following page will be found the program of the meeting. Judge Gary, President of the Institute, presided at the morning session. At the request of the President, Mr. William A. Rogers, a Director of the Institute, presided during the afternoon session. Judge Gary acted as toastmaster at the banquet in the evening.

PROGRAM—MAY MEETING

FORENOON SESSION.

Address of the President.............................ELBERT H. GARY
Chairman, United States Steel Corporation, New York.

The Development of the Iron and Steel Industry in Australia..DAVID BAKER
General Manager, The Broken Hill Proprietary Company, Newcastle, New South Wales, Australia.

The Relation of the Doctor to the Steel Plant............LOYAL A. SHOUDY
Chief Surgeon, Bethlehem Steel Corporation, Bethlehem, Pa.

Industrial Housing..................................C. L. WOOLDRIDGE
General Superintendent, Carnegie Land Company, Pittsburgh, Pa.

Discussion...R. H. STEVENS
Chief Engineer, Midvale Steel & Ordnance Company, Philadelphia, Pa.

Discussion...PAUL C. KUEGLE
Manager, Buckeye Land Company, Youngstown, Ohio.

Discussion...WALTER J. RILEY
Vice-President, Indiana Harbor Homes Company, Indiana Harbor, Ind.

AFTERNOON SESSION

The General Effect of Electrification on the Operation of Steel Mills...WILFRED SYKES
Assistant to Operating Vice-President, The Steel and Tube Company of America, Chicago, Ill.

Discussion...D. M. PETTY
Superintendent of Electrical Department, Bethlehem Steel Company, Bethlehem, Pa.

Discussion...R. W. COUSINS
Electrical Engineer, Indiana Steel Company, Gary, Ind.

The Importance of the Iron Ores of the Adirondack Region.FRANK L. NASON
Consulting Geologist, Witherbee, Sherman & Company, New York.

Methods of Using Fuel in Open-Hearth Furnaces..HERBERT F. MILLER, JR.
Assistant Superintendent, Lackawanna Steel Co., Buffalo, New York.

Discussion...M. J. DEVANEY
Superintendent No. 2 Open-Hearth Dept., South Works, Illinois Steel Co., South Chicago, Ill.

Gas and Air Valves for Open-Hearth Furnaces..............W. C. BULMER
Superintendent Open-Hearth Department, Ohio Works, Carnegie Steel Company, Youngstown, Ohio.

Discussion...F. L. TOY
Superintendent Open-Hearth Department, Homestead Works, Carnegie Steel Co., Munhall, Pa.

EVENING SESSION.

Impromptu Remarks in Response to Call of the President.

ADDRESS OF THE PRESIDENT

Elbert H. Gary

Chairman, United States Steel Corporation, New York

Gentlemen, these functions are especially notable for two things, and considerable comment has been made concerning these features by those who have had the opportunity to witness them.

First, it is rather remarkable that so large a gathering of people can assemble with so little disturbance both at the opening of the morning meeting and at the large banquet of the evening. That is the effect of the experienced and trained mind of a gentleman.

Secondly, that at all of these meetings, whatever time of the year they may be held, regardless of the necessity or at least desire for being home at one's business, so many should be able to attend and pay attention to the affairs of the American Iron and Steel Institute.

I take it the principal reason which calls so many men together under all the circumstances is that you find it very profitable to be here, regardless of the splendid papers which are produced from time to time by the members of the Institute; it is profitable to you because you come into close contact and fellowship with as fine a lot of men as ever gathered anywhere, and you find the intercourse is beneficial because you make and retain friends in the business world, which friendship is as strong and binding and desirable as even the friendships of social life. It is only men of high instincts, of superior thought, who can enjoy such business fellowship as you. Then, also, it gives you an opportunity to discuss many of the questions pertinent to national and state affairs, in which we are all much interested, and besides

you learn something that is valuable and may be applied to your business lives. Some of us wonder that the American Iron and Steel Institute, of such small proportions at the beginning, eleven or twelve years ago, should have grown to such large dimensions; that you have made the Institute what it is and what it stands for. It is because we take pride in it, because we have placed it on a high platform of ethics and business intercourse. I trust that there never will be any decrease in your interest.

The directors of the Institute whom you have placed in office from time to time very much appreciate your loyalty, your fidelity, your assistance in keeping together this great organization; and in behalf of the directors, I may assure you, gentlemen, that those men give as much and as close attention to the affairs of the Institute as the directors of your respective concerns give to the business in their charge. You would be surprised if you knew how much individual work in behalf of the Institute is done by its directors.

At the outset it is my painful duty to call your attention to the death of our esteemed comrade, our most distinguished associate, of world-wide reputation, honorary member of this Institute, admired and beloved by us all, Dr. Henry M. Howe; and in silent, reverent, affectionate testimony of his worth and of our grief at his departure I ask you to rise to your feet. (The gentlemen assembled arose.)

Gentlemen, we have a considerable program this morning. We may not be able to complete it during the forenoon. There will be some surprises, or at least one surprise, and I will let you wonder what it is for just a few moments.

I think some of you would like to know briefly what occurred at the White House last week, Thursday evening. You know by the newspapers that a little over forty representative members of the Iron and Steel Institute were invited by the President of the United States

to dine with him at the White House. There have been accurate accounts printed; and in addition a good many unjustified suggestions or hints have been made concerning the dinner. It was very simple, homelike, frank. The steel industry, or any part of it, has no reason to complain of the attitude shown by President Harding. The speaking, which included nearly all of the guests of the evening, and would have included them all except for lack of time, was done from the chairs of the gentlemen while sitting, rather than in the ordinary, formal way of standing. The President believed this would be more cordial, more homelike, more frank, and would probably be productive of engaging in the conversational discussion many who would be embarrassed if they were standing. I did say to him that if he knew as well as I how well the steel people talked standing on their feet, he would have no concern in regard to their ability to forcibly and clearly express themselves. Then he retorted by generously saying he was speaking more in his own behalf than any other's. He said, "I generally know what I am going to say, in substance, and I have nothing whatever prepared; and I have nothing prepared because I would not know what to prepare, or what to say."

Then the President frankly told all of us present what was in his mind. He said, I want to talk and to hear you talk about the twelve-hour day. However, at the outset, I declare that I have no intention of intermeddling, or interrupting, and least of all injuring the iron and steel industry, or any branch of the industry, of this country. I think there is a well defined and perhaps a growing sentiment throughout the country against the twelve-hour day and in favor of its total abolishment. It seems clear that this cannot be done successfully except by the concerted disposition and action of the iron and steel industry. I think that if we can consistently get rid of this practice of the twelve-hour day it ought to be done, and that is as far as I go. I do not propose to insist upon or to urge my views upon others, except

as they may appear to them to be reasonable, and appropriate. If I can be of benefit, if I can help in bringing about this change, which has been demanded by certain portions of the public, it would be very agreeable to me.

Then the President called upon many of us who were present to express our views, which we did.

We told the President that first and best of all the iron and steel industry appreciated the disposition of the President of the United States to call into an intimate relationship and into a frank consultation a representation of the whole industry to discuss questions which might appear to be more or less of public interest and which was of very great if not vital concern to the industry itself.

We told the President we believed it was the desire of the industry to get rid of the twelve-hour day if it were desirable from every standpoint, including the workmen themselves. And then we told him in more or less detail, some much more than others, of the difficulties which stood in the way, and the efforts which had been made and were being made.

We tried to impress upon the President's mind the thought that the man who is engaged in labor which is extremely burdensome, did not work more than eight hours per day in our mills or our furnaces, and that the men who worked twelve hours a day as a rule did not have extremely hard labor to perform and that they were actually engaged not more than half the time in actual work. We told him of the desire of our men, many if not most of whom are foreigners, to earn the largest sum per day which was practicable; that generally the amount found in the pay envelope on pay day was of the highest importance to the men themselves.

We told the President frankly that we knew of the public expressions which had been made, many no doubt in good faith, and others as a sort of propaganda by people who were not accustomed to work and who were not very well informed; but that there was a public senti-

ment against twelve hours we did not deny and that we believed the iron and steel industry would be glad to meet the wishes of the public and of the workmen, if and when it seemed possible to do it.

Some of our speakers called attention to the fact that it was believed this question was largely one between the employers, including the workmen themselves, and the purchasing public, who paid for the extra or additional costs in production which might result from decreasing the hours of labor.

We told the President that we were open minded, that we intended to be fair minded, and to do the right thing always; that we believed the public interest was of the highest concern always and that our interests should be subordinated; and especially when the President of the United States was desirous of accomplishing a result, we should to the fullest of our ability cooperate with him and give proof of our willingness to be fair.

I think the President appreciated the disposition of the industry, as explained. I believe he comprehended that there were difficulties. And yet he showed signs of being in dead earnest, in his endeavor to bring about this change, if it could be done; that he relied upon us to bring it about if possible.

After this discussion it was moved by one of the steel gentlemen, and agreed unanimously, that a committee be appointed by the President of the American Iron and Steel Institute to make a careful investigation, ascertain all the facts applicable, and after giving most careful and studious thought to report their recommendations to the iron and steel industry. That is where the matter stands.

Let me say that during the day after I have had full opportunity of consulting the directors of the American Iron and Steel Institute I will appoint this committee. We talked first of five members. I think there should be more. I do not think we can fairly represent the different phases and localities of the industry unless there are

nine members. The investigation must be fair, just, intelligent and representative. There will be no disposition to establish a committee which is prejudiced for or against; but, rather, one whose minds are open and unbiased.

Gentlemen, you can be of assistance to that committee. In fact, in justice to yourselves, to the industry generally, to the general public, and above all to the President of the United States, who meets us on common ground, having in his heart only the desire to see that the right thing is done at the right time, when business is improving and labor is liable to become more scarce, in justice to him we think that every one of you, through all the sources of information under your control, should furnish to this committee your written views, signed by your highest officers, or heads of firms, which bear upon this question, a statement worthy of being read, and fit to print, and which will be of the greatest assistance to this country and to the world, so that thereafter there will be no good reason for any man or any interest or any publication to assail the iron and steel industry for having permitted the twelve-hour day unless good reasons are shown from the facts on which to base the criticism.

Here is your opportunity to put yourselves on record; and it is not too much to say when I assert that upon you is a part of the responsibility: you must share with this committee the responsibility of making a report that is worthy of consideration and adoption. And may I add to that, gentlemen, you should commence this investigation, and you must make your recommendations to the committee, with the determination in advance to find ways and means of getting rid of the twelve-hour day, if it can be done.

It depends a good deal upon how any one considering a question of this importance approaches the subject. If he is trying to find a way not to do a thing, he is more apt to find that way than if he is disposed in advance

to do it. I do not think our committee will attempt to influence your judgment, or your action, or your study, nor to ask you to do more than to go at the subject with a view of assisting to find a way to get rid of the twelve-hour day, if you can. But when you make up your mind honestly, intelligently, based upon the facts, you are justified in expressing the opinion which you conscientiously reach. That, no more and no less, our committee expects.

Legislation

The prosperity and welfare of all the people depend upon the enactment, the administration and the enforcement of law. It furnishes the fundamental distinction between human beings of today and the cave dwellers of the past.

All fair-minded, right thinking men and women will agree that laws should be adopted, maintained and enforced strictly on the basis of equal opportunity and equal responsibility to every man, woman and child, wherever located and whatever the surrounding circumstances may be.

Any law in its existence or its administration that discriminates in favor of or against any individual, calling or location is essentially wrong and is injurious to the whole body politic. Any person who, for selfish reasons or as an advocate for another, insists upon a claim contrary to the one expressed is disloyal to the principles of our national scheme of government.

These principles should always be borne in mind by the executive, the legislative and the judicial departments of Government; by the farmer, the merchant, the banker, the carrier, the manufacturer, the miner, the employer, the employe, the possessors of capital and the impecunious; and in these days particularly they should be constantly emphasized in the minds of all professionals — those who attempt to instruct or to minister to the wants of others.

I trust we of the iron and steel industry are conscious of our obligations to the laws of the land, to the general public and to our neighbors, those with whom we come into business contact. This should be our constant thought and study. This is a substantial part, nay, the controlling spirit of this Institute.

On the other hand, we have the right to insist that all others shall be required to conform to the same strict accountability; and that we shall receive the same protection and benefits that are accorded to others. As the prosperity of the country is vitally affected by the passage and administration of laws, even by the tinkering of legislation, so called, it is deemed appropriate to discuss before the business men of an important manufacturing industry some of the current proposed legislation, even though what we may say or think may have little influence.

Tariff Legislation

Revision of tariff laws is an intermittent disease. It appears, if not with every session of Congress, certainly with every change of administration. It seems to be considered an important political question, though it ought not to be. It should be discussed and decided strictly upon scientific principles and from the standpoint of fairness to every part of the country, to every department of human industry, to every line of employment and to the public welfare. This was the tendency of public discussions for a time, but it seems there has been an increasing departure from this practice; that the data secured by the National Tariff Commission at large expense has been almost completely ignored in late discussions.

Many years ago I was invited to the White House to consider briefly tariff matters. I commenced by saying: "Mr. President, I favor free trade," and, after waiting for the surprised expression of countenance

which appeared, finished by saying, facetiously of course, "for every industry except our own." President Roosevelt, immediately catching the point, replied: "That is exactly the trouble. They laughed Hancock 'out of court' for saying the tariff was a local issue, but he was nevertheless perfectly accurate." This little incident illustrates what has always appeared prominent in Congressional investigations and decisions, and the disposition has been shown to the same extent in both parties. Efforts to obtain personal advantage have not been limited to localities, individuals, industries or commodities; they have been universal. Every member of Congress, striving to faithfully represent his own constituency, is more or less selfish and, by argument, persuasion, and sometimes, if rarely, by bargain with other members, contends for and often secures benefits which are more or less local.

As between parties the main difference, as I see it, is that the Republican party has stood for a "protective tariff" and the Democratic party a "tariff for revenue," whatever the distinction may be or is claimed to be. The settlement of this controversy should include both. Indeed, if the question is settled right there must be both. The evil, if any, results from going to extremes. If the two parties could agree upon principles, as they ought to do, the tariff question would be removed from politics, and business progress would not be disturbed by pending legislation relating to it.

Tariff rates should be high enough to protect all producers in this country, including capital and labor, against destructive foreign competition, which may come from cheap labor or otherwise, and might drive both domestic capital and labor out of employment. They should protect domestic production fully up to the point of being on a parity with all foreigners as to selling prices in the United States; but they should not be high enough to permit producers to oppress consumers by unreasonable and unconscionable prices.

The determination, from time to time, of this basis, that is, the full and fair application of the principle stated, would involve careful and scientific study and be more or less difficult, but it would not be political. There should be a commission of well paid, high minded, intelligent, competent and non-partisan appointees, authorized to ascertain and communicate the facts and figures, and their reports should be frequent so that, if deemed necessary, a change in or amendment to the tariff laws or any of them could be made at any time Congress is in session. Its members would or should confine their discussions to the question as to whether or not the recommendations came within the principles named.

If tariff laws should be based entirely on the amount to be collected for revenue great injustice might be done the consumer. There are many kinds of imports that are not produced in the United States. On these, if revenue alone is considered, the amount of tax might be unlimited, except as determined by the absolute necessity or the willingness to buy, and it might be oppressive; but while this would add to the treasury of the revenue collector, it would come out of the consumer and, to the extent that it was excessive, it would be oppressive.

Fair and reasonable protection to industry, no oppression to the consumers, this is the line to be established and maintained up to the highest point of possibility. To this principle I think we may safely and conscientiously subscribe. For its application good business will lend its influence.

We have able, fair-minded men in Congress and they are not afraid to vote against tariff rates they believe are too high or too low. It is to be hoped the tariff agitation now pending will soon be ended and that the bill adopted will not especially help or hurt either political party, and that it will help business.

Governmental Regulation

Legislative enactments or the modification or extension of existing laws for the regulation of industry are being frequently debated in and out of Congress and, personally, I welcome this in so far as it is sincere, unselfish and non-partisan.

Almost as a matter of course the majority of individuals or associations, if they themselves are exempt and unmolested, are quite willing and even anxious to have all others subjected to the most rigid governmental investigation and exposure to the public.

Investigation and publication are proper and desirable, if not carried to excess. Constant, partisan and reckless indulgence in this pastime by representatives of government, or, what is much worse, by self-appointed, unqualified or dishonest individuals or associations, posing as public benefactors, may be and often is misleading and antagonistic to the general welfare.

At other times I have said that occasional investigation of investigators might result in exposure of a good many rascals; and I emphasize the statement. It is a trite saying that often the man who cries "stop thief" in the loudest tones has the stolen goods in his pocket.

If a man by his manner and methods gives evidence of personal hostility or selfish designs, it is well to scrutinize his conduct and motives before giving credit for his work or placing reliance upon his statements. He may be a "wolf in sheep's clothing."

We may concede that searching inquiry is sometimes necessary and generally productive of good and still be justified in characterizing many of the investigations and investigators as a public nuisance, especially if there is an attempt to go beyond the legitimate domain of the examination, and more particularly, if misrepresentations or unfair methods are indulged in.

When it comes to our industry or any other important

branch of economic activity, as you know, I have always favored reasonable publicity. I know some of you may believe I have gone too far in my expressions of opinion upon this subject, but I have endeavored to look to the future and to consider the question from all sides and from the standpoint of the best interests of all.

From the mere view of successful operation, perhaps most of us might admit that private business can be better managed by the owners without any public interference or oversight, though there are two sides to this question; but if conceded, it seems to me to be fair and reasonable that big business, with all its advantages and power, should be subjected to governmental inquiry and supervision, provided it is through a non-partisan, non-personal, thoroughly qualified commission, and shall always be subject to review and determination on the merits by the highest judicial tribunal. The courts of our country are the bulwark of protection and safety. They are able, impartial and honest. They may be assailed, even as righteousness itself may be assaulted, but, if so, with exceedingly rare exceptions, it is because they *are* worthy and the man who attacks is unworthy. By his very actions or words he is self-condemned.

But the insistence that governmental regulation of industry is proper and desirable should always be accompanied by the condition that there shall be no discrimination; that all lines and departments of economic activity of similar importance shall be subjected to the same treatment.

The progress and prosperity of no nation can long endure if any single factor in economic life shall be especially favored or punished or exempted. Equality before the law is fundamental to industrial peace and prosperity.

The consideration of mere personal and private benefit or injury to any single factor in our industrial life, has no proper place in the genius of our nation.

The thoughts suggested arise from the disposition

during the last few years to pass laws which measurably exempt labor organizations, and recently farmer associations, from governmental investigation, supervision and control against wrong. Not only are they exempted from certain restrictive provisions of the existing statutes, but they are affirmatively permitted to do certain things prohibited as to others.

To permit labor associations or farmer organizations to do, as the result of combination, things that are claimed to be beneficial to them which are denied to others is to create classes, to favor some of them and to injure the whole body politic. It tends to array class against class, and it adds to the cost of production. And be it remembered the general purchasing public, in the end, must pay the bills. This, as a net result, is certain. This is not equal opportunity and equal obligation. I willingly admit as to labor, towards which no one has better intentions than I, that in the long past, as the result of class existence, it was not justly treated. Also, I know by experience and otherwise, that the farmers, the most essential element of our national life, have not uniformly received adequate financial returns on their investment and labor. I was born and bred on my father's farm. I was a laborer in the true sense, both as to hard work and long hours.

But what I have said concerning the farmer, who, as a rule, is both capitalist or manager and workman, and about the laborers, who also are often possessed of capital, in no respect militates against the claims I have made.

If it is necessary, in order to protect workmen against imposition, to permit them to organize into associations and thus act collectively, let it be done under and by virtue of the general laws, subject in management to governmental investigation and supervision and control against wrong, oppression and violence. Let them account, under direction of the Government, for moneys

received and disbursed. And the same argument applies to farmers.

Treat all persons, all organizations, of equal importance, as essential parts of a nation, each as good and as bad as the others. Even treat them as children, if necessary, subject to discipline; but in that case compel Uncle Sam to treat them with the solicitude and to afford them the protection that ought to be required of a father.

Governmental regulation of industry, in my opinion, will never be a satisfactory and permanent success unless and until it is fair and reasonable and, above everything else, is applied without discrimination. If any congressman contends for legislation that especially favors or punishes any class or division of industry, it should be with the avowed understanding that it is intended to be contrary to the general spirit of our Constitution.

Soldiers' Bonus

For many months last past there has been much discussion in the public press, in the halls of Congress and elsewhere, relating to a bonus to those who served in the late war. There has been considerable propaganda in behalf of this proposal. Personalities and vituperative comment have been indulged in. Prejudices have been created. High Government officials, United States Senators and Representatives, have been importuned and, to a certain extent, abused for opposition to or lack of interest in the "soldiers' cause." National ingratitude for loyalty and sacrifice has been charged. Legislation has been proposed, amended, discussed and halted. Because of this situation a feeling of unrest and resentment has arisen, and the effect upon the natural progress of efforts to return to the normal conditions of peace and industry has been depressing.

It is not necessary nor intended at this time to discuss the merits of a public or private demand for the payment, as a bonus or reward, to millions of soldiers involving billions of dollars. Even though there may be two sides

to the question as to whether or not a soldier who has escaped disability, physical and mental, should be paid or should ask the payment of a bonus, it would not be useful for us to consider or form opinions on that question at present. In my judgment it is not yet ripe for determination. The final disposition of it should be deferred.

Manifestly the people of the United States, taken as a whole, are vitally interested in a quick return to normal and prosperous economic conditions. To insure physical comfort and happiness to all the inhabitants the wheels of industry must be running continually and continuously. However rich in gold or property a nation may be, it is obvious that unless the wealth is used in production of physical necessities and at the same time employment is provided for all who are able and desire to work, the idle capital will be of little value or benefit.

The people of this country, for the present at least, cannot afford to pay or appropriate the large bonus for soldiers which has been suggested. The burdens of taxation resulting from the war are already too heavy to carry without materially and adversely affecting the full return to prosperity. There should be, right now, extensions and new developments of enterprise in many directions; but delay or abandonment is made necessary for lack of ready money on account of taxation.

One who follows the published figures or who by personal inquiry and observation is familiar with the facts must be convinced that because of the heavy taxes this country is not reaping the natural benefit of its opportunities. We need not be despondent; nor, on the other hand, would it be wise to shut our eyes to unfavorable facts or symptoms.

Former soldiers, like all others, need opportunity to work in any and all lines of employment and, to continuously furnish this chance, courage and capital should be given to industry. The load of taxation ought to be lightened, not increased. Enterprise has staggered under this

burden. It would not be difficult to break its back. These are not idle words. They are a solemn warning, not only to soldiers, but to everyone who is at present seeking what is neither reasonable nor patriotic; also to any who claim from the Government what it is not able to pay without increasing the national debt, thus adding to the taxes and impeding the legitimate progress of the army of industrious men and women.

We must bear in mind that in the payment of bills or the receipt of benefits, the people as a whole finally share in the results, even though there may be temporary gain or loss to individuals.

Therefore I do not hesitate to say that if and when there is paid a bonus to soldiers the amount should be provided by a species of taxation which is universally distributed. More than this, I think, in accordance with principles already referred to, all taxes should be assessed and collected in proportion to benefits derived and the ability to pay. This is represented by the possession of property or the expenditure of money. Property is accumulated, as a rule, in accordance with the disposition to work with the hands or mind, to economize, to save, to carefully and wisely manage, so that some add to their holdings more than others; some are more liberal, if not extravagant, than others in expenditure.

The fairest method of taxation is found in the sales tax, so called. It is the most easily, cheaply and certainly collected. It has been found in other countries to be practicable, satisfactory and successful. The tendency is to make persons more economical and saving. The sales tax is just because it leaves to everyone the opportunity to decide what the amount shall be over and above actual necessity. It is less difficult to collect large amounts and works less hardship to honest people because it is so widely distributed. A cent each to twenty men is twice as much as ten cents to one man. Under the present income tax laws the cost of collection is unreasonably large, and many who are able to pay escape. For the

good of all the people as a net result a sales tax is desirable.

I verily believe with a fair sales tax business would be better, the country would be more prosperous, individual opportunity increased and everyone made happier. Every plan which is just and applies in due proportion to all the people, in benefits or obligations, is likely to be the most satisfactory and to build up the nation on a sound and safe foundation. Those who have read with open and candid minds the many very able articles and editorials on this subject which have appeared in the newspapers must be convinced of the logic and fairness of this form of taxation.

It is hardly necessary, if proper, to refer to possible legislation relating to the payment or cancellation of the sums due our country by foreign nations. For the good of both creditor and debtor all honest debts should be paid, if possible, though a generous and humane creditor will always be liberal in extending the date of payment in times of urgency.

There are many other bills pending in Congress, some of which bear upon the subject of economic progress. This is not peculiar to the present session. It is a general habit. There is often, perhaps usually, a sense of relief when legislative adjournments are announced, but this is true of all public conventions. It is because of fear that something hurtful may happen, though as a matter of fact most of the fears prove to have been groundless. Even the mere appropriation bills which provide the necessary funds for governmental administration often precipitate trouble and demoralization and occasionally business depression. It is not so much that large expenditures are proposed as it is the spirit generally exhibited to which we object. Selfishness, greed and vindictiveness are displayed. Not infrequently efforts to promote political or personal advancement are strongly in evidence. Many things other than the public welfare are apparent. The influence of cliques representing capital or labor, or

other factions, is often present. Congressmen are like the ordinary run of individuals—most of them honest and well intentioned, but a few possessed of less merit.

The idiosyncrasies of individuals occupying places in legislative halls are no better and no worse than they are in other places. As the world grows better its inhabitants will more and more exercise care and common sense in the selection of their representatives. This is inserted as a tone of consolation and hope.

Business Conditions and Prospects

Since the armistice of 1918 I have never spoken publicly without referring, though with brevity, to the signs of danger and depression, the possibility of demoralization and disaster as the result of the military cataclysm which for four years and more convulsed the world. We have not, I think, entirely passed from under the clouds of adversity. Certainly we are carrying hitherto unheard-of heavy governmental financial burdens. At best, these will not soon be fully discharged. To bear them gracefully and contentedly there must be not only forbearance, encouragement and assistance from every department of government up to the limit of propriety and justice, but there must also be entertained by every individual, consistently and constantly, a spirit of patience, pluck, energy, generosity, loyalty and charity fully up to his or her highest intelligence.

Gentlemen here assembled, we must do our part. We must be fair and just, as loyal to the Government as we were during the war. We must treat others in such manner as to be entitled to their approval.

Little need be said about the changed and changing business conditions for the better in the iron and steel industry. The facts and figures have been and are being published. The volume is large and increasing. The profits are not satisfactory but few, if any, ought to be doing business at a loss, and we shall, soon I hope, settle down to a readjusted basis of prices and rates that is

fair and reasonable and on a comparative parity. Let us be moderate in our demands. Profiteering will be more and more exposed and eliminated. I could if necessary refer to some outrages that still exist; but the general public, when correctly informed, is disposed to be just and it will not long overlook nor condone the exceptional glaring injustices that still obtain in prices and rates.

Ever since the armistice was signed, when I have spoken it has been hopefully as to the long business future. I am still an optimist. And likewise are you. It is seen in your countenances. Big, even profitable, business has been ahead of us all these years, though it has been at times obscured. Now we seem to be nearer a realization. But every one in official or private life, employers and workmen, professionalists, merchants, financiers, mechanics, artisans, all, properly supported by our Government, may and will, as never before, utilize to the greatest advantage of our own people and others the existing and productive wealth of this great country.

Optimism arises from opening one's eyes and ears and mind to the good things in life which a merciful and overruling Providence has bestowed. May all of us have sense to appreciate. Pity the chronic blind, deaf and foolish pessimist of the United States. (Applause).

Judge Gary: We happen to have present with us this morning a distinguished gentleman from London. While he is at the head of a very large accounting firm, having offices in different countries, including our own, he is a factor in the iron and steel industry, that those of us who know him well thoroughly appreciate.

When we were fortunate in having, as our guests, groups of distinguished iron and steel men from all the iron and steel producers of the world, there was included the gentleman to whom I have reference. And in 1911, when there was called and organized a convention of representatives of the iron and steel men of all the steel

producing countries, in Belgium, this gentleman was prominent in the British group, prominent in looking after our interests, and in entertaining us most royally in England; and later, in Belgium, as general secretary he took charge of the convention, keeping everything in line, looking after the reports and the reporting, the various special committees, and finally in publishing our proceedings and our speeches, both at the splendid banquet in London at which the Duke of Devonshire presided, and afterwards at the fine banquet which was given in Brussels; and as a general all around well known, highly respected and trusted general manager, I may say, of the convention, and of our visit, this man secured our abiding esteem and confidence.

Now he happens to be in New York on business of his own at the present time and, because it was the only time he could spare on account of other engagements he had made, social and otherwise, he is with us this morning. It is my very great pleasure to introduce to you Sir William B. Peat of London.

Sir William B. Peat: Mr. President and gentlemen: It is a long time as time goes, a decade past, since I had the opportunity and the pleasure of attending the first meeting of the American Iron and Steel Institute.

I suppose Judge Gary invites me to come to you from our small country and our English iron and steel producers, to survey the greatness of the United States of America Iron and Steel Institute. I am greatly impressed with the magnificence of the Institute which you have built around about you and which that short decade of years has converted from an infant into something of great growth and great importance in the world.

When I called at the request of some of our steel makers in the United Kingdom to bear a message of good will and appreciation to your President, he informed me of this meeting, and I have the very greatest pleasure in being present.

I have no message for the steel makers of the United

States except the good one of peace and good will from our side of the country to your side of the country, and to express the hope that the carrying on of the steel trade, which is international, will be conducted with kindness and consideration for the common interests and that all rivalries which may exist will do nothing to interfere with the friendly relations which must and ought to exist between every country which produces iron and steel.

My message to Judge Gary was sent by those who feel he is for you a national asset; but for us, an international asset. If anyone can guide the destinies of the steel trade of the world in peaceful channels, progressive channels, just channels, with justice to all who enter into that great manufacture, it is Judge Gary. (Applause.)

I know that not alone from manufacturers of the United Kingdom, but from manufacturers in every part of the world, from France, Belgium, Luxemburg, as well as the United Kingdom, many of whom I know very well, associate in one thing, if not in many others, and that one thing is in readily appreciating the value which Judge Gary has been not only to those he immediately represents but to those who have the honor, or the profit, or the loss, in carrying on the steel industry in other countries.

Sometimes I say, gentlemen:

> "Oh wad some power the giftie gi'e us,
> To see ourselves as others see us!"

If it were given to me to possess the power to explain to you gentlemen how others see you, I would attempt in a very few words to do so.

Others see you gentlemen in this great country of which you are citizens as a vast, progressive nation, a force in the world: an economic force in the world which has never been equalled since the days of the early part of last century when our own United Kingdom took the form of supporting, of assisting financially and develop-

ing the world trade, which it has gone on developing until this war took place.

I am happy to think that this great force, the United States of America, will progress and will begin to see that what you do in the form of supporting other countries is done with wisdom and judgment. You have all the money bags in the world stored somewhere in New York; you cannot eat them. You have all the debts, three thousand millions sterling I believe, owing to you, by various countries; but you cannot secure those debts unless they are secured out of the products of goods and services of those who are your debtors. You cannot utilize your money bags except by promoting industry in some other country, because it is no use to export your gold; you will export the goods which represent that gold; you will ship such goods to other countries in its turn to become productive. Trade is an international something, you cannot be everlastingly sending full ships out of New York Harbor and having empty ships coming back; if you are to export your material, it is important and absolutely necessary that you import material or services to balance them. The whole world is one workshop; it is an international workshop in which every unit adds its part in supplying every other unit with the things that other unit requires, and exporting the things which other units need.

I will not weary you by remarks of that character. I express merely my own personal opinion, an opinion which no one else may endorse or accept.

I wish for the American Iron and Steel Institute that if it is possible every decade may see the progress which the past decade has experienced. I am known to a few of you, but only a few of you, because a new generation has risen up who know not the Joseph of old.

I thank you for your patience in listening to me, and I thank Judge Gary for the kindly, courteous way in which he introduced me to you gentlemen. (Applause.)

JUDGE GARY: I think now there should be an oppor-

tunity to the many who are here to comment on the President's remarks or on the speech of Sir William, and that opportunity is now afforded.

Mr. Clarence Howard: I would like to say just one word. I believe that your address was most timely, and touched upon the subjects on which this government is so dependent at this time, and I want to be one to thank you for it. I feel the world will be better after having read it. (Applause.)

Judge Gary: I think perhaps I ought to say at this time that we shall have with us this evening at the banquet Field Marshal, the Right Honorable the Earl French of Ypres. You will be glad to see him and hear him speak. (Applause.)

We shall now have the pleasure of listening to an essay, or the substance of it, on The Development of the Iron and Steel Industry in Australia, by David Baker, general manager, The Broken Hill Proprietary Company, Newcastle, New South Wales, Australia.

Mr. Baker's paper was sent to the Institute with the request that it be read by Mr. Harold L. Hughes, formerly Australian manager of the United States Steel Products Company. Mr. Hughes himself is thoroughly acquainted with the developments in Australia, familiar with this paper, a friend of Mr. Baker, and will treat the subject by way of condensation as seems most appropriate.

THE DEVELOPMENT OF THE IRON AND STEEL INDUSTRY IN AUSTRALIA

David Baker

General Manager, The Broken Hill Proprietary Company, Newcastle, New South Wales, Australia

This farthest outpost of the British Empire occupies the unique position of a colony of a little over 5,000,000 people holding undisputed sway over a whole continent with an area greater than that of the United States of America, excluding Alaska and other non-contiguous territories.

This all-British community with its undeveloped, in fact unexplored, resources is one of the most important sections of the great Empire of which it forms a part, due to its location entirely in the tropical and temperate zones, its mineral wealth, pastoral resources, position in the South Pacific, and the independence, virility, and loyalty of its population.

From Government records we learn that the European navigators who first reached the shores of Australia found the inhabitants without iron; neither have there since been discovered heaps of cinder, nor other relics of ancient iron industries. The aborigines fought, hunted, and etched rude pictures upon the rocks with implements formed either of wood or stone. Being situated in a remote corner of the world, they were not likely, during prehistoric times, to become acquainted with the arts of iron manufacture in vogue elsewhere; while a low order of intelligence, and the absence of a desire to improve their condition, would prevent them from evolving a system of their own.

Iron Ore Deposits

As the discovery of iron ore deposits in the Commonwealth is associated with the early attempts at iron making, this latter development will be considered in connection with the description of the ore deposits of each State.

Western Australia

The most important deposits in this State are the deposits of Koolan and Cockatoo Islands in Yampi Sound.

Koolan Island Deposit, Yampi Sound. The main deposit stands out abruptly above high water level to a height, in places, of 600 feet. Mr. Montgomery, the State Mining Engineer, reports that the deposit has a length of 300 chains and an average width at the base of 110 feet. There are estimated to be 68,850,000 tons of iron ore averaging about 65% iron, 6% silica, .06% phosphorus, and a trace of titanium oxide.

On the northern end of Koolan Island there is another deposit, estimated to contain 7,800,000 tons averaging 66% iron, 5% silica, .04% phosphorus, and .35% titanium oxide.

Cockatoo Island Deposits, Yampi Sound. Mr. Montgomery reports that there is a deposit of hematite outcropping for a length of 110 chains up to 300 feet in height, and about 130 feet in width—estimated tonnage available above high water level 13,850,000 tons, averaging about 68% iron and 2% silica. Another deposit occurs on the northern end of this island, and is estimated to contain 7,000,000 tons of iron ore.

Iron ore deposits are widely distributed in this State, but some of the richest and most extensive deposits are valueless owing to their geographical position.

South Australia

The ironstone deposits of this State are very numerous, but the only ones that have been extensively worked

are the Iron Knob and Iron Monarch deposits, owned by The Broken Hill Proprietary Company, Limited. These deposits were worked and originally supplied flux to the lead smelters at Port Pirie, but are now utilized for the supply of iron ore for the Company's Iron and Steel Works at Newcastle, New South Wales.

In the Iron Monarch and Iron Knob, on the western shore of Spencer's Gulf, South Australia, there exists a large deposit of iron ore, estimated by Mr. H. Y.

Fig. 1—Outline map of Australia, showing location of iron ore deposits and of the principal coal field.

Brown, Government Geologist of South Australia, to amount to at least 21,000,000 tons. This computation has since been shown to be a very conservative one, and a later Geological report puts the estimated ore reserves at 130,000,000 tons. Later exploration in this vicinity by the Company has proved two further valuable deposits of iron ore, which have been named the "Iron Prince" and the "Iron Baron."

A small charcoal blast furnace was erected near Mount Jagger, about 11 miles north of Victor Harbour,

in 1873. Ore was obtained from an extensive deposit of magnetic iron ore which caps the summit of Mount Jagger. Owing to the workmen not being sufficiently skillful, the furnace frequently became blocked and operations were not successful.

Victoria

Professor Krause estimates the Lal Lal deposit to have 750,000 tons of available ore, containing 68% to 70% oxide of iron, 16% silica, and a trace of phosphorus.

Deposits of hematite occur at Nowa Nowa, with which are associated magnetite and specular iron. Deposits of iron ore occur in many places, but very little data is available concerning them.

About 1875 a small experimental blast furnace was erected at Lal Lal, near Ballarat, and a small quantity of pig iron produced from iron ore, which forms a crust upon the older rocks in this locality.

Tasmania

The following is a summary of the iron ore deposits of Tasmania supplied by the Geological Survey in their publication "The Mineral Resources," No. 6, 1919:—

Districts	Potential Tons
Blythe River lode	17,000,000
Dial Range and Penguin	700,000
Beaconsfield and Anderson's Creek	1,300,000
Long Plain	20,000,000
Zeehan District	2,900,000
Nelson River	Unknown
Total	41,900,000

Of these, the Blythe River iron deposits seem to be the most important, and analyses quoted by Mr. Ward, Government Geologist, show that the iron contents vary from 46% to 68.7%, the silica contents from 1.6% to 34.2%, and the phosphorus contents from 0.04% to 0.09%.

The Commonwealth Government recently engaged three mining engineers to report on this property, who summed up the position by reporting that in their opinion the lode-matter as a whole was too silicious for commercial iron ore.

The British and Tasmanian Charcoal Iron Company was formed between the years 1872 and 1875 to exploit the iron ore deposits in the Beaconsfield district. The sum of £80,000 was expended in erecting works, and several hundred tons of pig iron were produced, but on account of its containing 5% chromium and not being adaptable to ordinary uses, the operations were not a financial success. Tool steel was made in experimental quantities in the year 1872, and in 1876 a blast furnace was blown in with coke as fuel, Bulli coal being coked in a battery of 40 coke ovens on the ground. In about ten months time, from 2,000 to 3,000 tons of pig iron were produced, and in 1877 the furnace was again in commission, producing about 250 tons of pig iron per week, containing from 2% to 10% chromium, which was used by Melbourne iron founders for making battery shoes and dies, also other articles requiring hardness and toughness. However, there was only a limited local market for this class of iron, and operations were suspended. It is stated that about 10,000 tons of pig iron were produced by this furnace, but notwithstanding experimental work and close observation, the pig could not be produced of a sufficiently soft nature, nor could uniformity be secured.

Queensland

Dr. Logan Jack refers to the enormous deposits of specular iron, hematite and magnetite in the Cloncurry Districts. One of these deposits, Mount Leviathan, is about 200 feet high, and a quarter of a mile in diameter at its base. He refers to the geographical position as "causing it at present to be absolutely valueless."

The Mount Biggendon district also has high-grade iron deposits from which bar iron of good quality has been produced by the Maryborough iron founders. The estimated quantity of ore available in this district is 500,000 tons.

State Iron and Steel Works. During the war a Royal Commission was appointed by the Queensland Government to enquire into the advisability of establishing State Iron and Steel Works in the State of Queensland, and a summary of their report is as follows:—

"Queensland is a vast State of magnificent distances, and although we have a greater mileage of railways than any other State (5,287 miles of Government lines opened for traffic, and 428 miles under construction), there are still many districts crying aloud for railways and tramways. If it is found that the State can do it, not a day should be lost in making our own steel rails, and in supplying the people of Queensland with all the requirements in iron and steel. When peace is declared it is certain there will be a big influx of people to Australia. Queensland, having the greatest area of unoccupied fertile land, will be called upon to provide facilities for more land settlement. Steel rails will therefore be greatly in demand for girdling the State with an iron band. With all the essentials for their successful manufacture within the control of the State, a new era of prosperity will dawn for Queensland as soon as they are assembled together, and the enterprise started on its way.

"We therefore unanimously recommend:—

(1) That the State proceed immediately with the erection of a furnace having a capacity of, say, 150 tons of iron ore per day, together with extensive by-product recovery coke ovens and mine equipment. The initial cost not to exceed £150,000; further sums to be expended if circumstances warrant an extension of the works.

(2) That a thoroughly qualified expert, with business and administrative ability, trained in metallurgical science and en-

gineering, and having a practical knowledge of modern iron and steel works, be appointed to the position of General Manager of the works, and, as such, be empowered to choose the most suitable site on which the plant should be erected.

(3) That the General Manager of the Iron Works be appointed by the Government to make further investigations and report on the following questions:

(a) The advisableness of establishing State Steel Manufacturing Works in Queensland.

(b) The cost of such works and capacity.

(c) Existing and potential markets in Queensland for iron and steel.

(d) The possibility of a market for export beyond the State.

At this writing, owing to the prevailing business depression, all work on the proposed iron and steel works for the State has been stopped, and while the General Manager is still retained, and the site for the works chosen, it is reported that all other employees of the Department have been dismissed.

New South Wales

The iron ore deposits of New South Wales are both numerous and scattered in their occurrence; the following is a summary of iron ore deposits in New South Wales by Mr. J. B. Jaquet in 1901, taken from publication, Geology No. 2, of the Geological Survey of New South Wales.

District.	Description of Ore	Estimated minimum quantity ore in tons.
Bredalbane	Brown ore and hematite	700,000
Cadia	Specular hematite, magnetite and carbonate ore	39,000,000
Carcoar	Hematite and brown ore	3,000,000
Chalybeate Spring—Deposits of Southern District	Brown ore	1,510,000
Cowra (Broula)	Magnetic ore	100,000
Goulburn	Brown ore	1,022,000
Gulgong	Magnetic ore	120,000
Mandurama and Woodstock	Brown ore	609,000
Marulan	Brown ore and hematite	40,000

District.	Description of Ore.	Estimated minimum quantity ore in tons.
Mudgee	Brown ore with manganese	150,000
Newbridge, Blayney and Orange	Brown ore and magnetic ore	150,000
Quenbeyan (Paddy's Point)	Magnetic ore	1,000,000
Rylstone and Cudgegong	Brown ore	443,000
Wallerawang and Piper's Flat	Brown ore	200,000
Williams and Karuah River	Titaniferous magnetic ore	1,973,000
Wingello	Aluminous ore	3,000,000
		53,017,000

The first attempt to manufacture pig iron in New South Wales was made at the Fitzroy Iron Works, near Mittagong on the Southern Railway. No complete account of the quantity of pig iron which was manufactured is available. In the returns published in the Annual Reports of the Department of Mines (1876-1886) mention is made of amounts which total 13,313 tons, but these returns are obviously incomplete.

The Fitzroy iron deposit is situated sixty miles from Sydney, and close to the road running between Sydney and Goulburn. The bright red and yellow oxides upon the surface must have always caused it to be observed by travellers, and the chalybeate spring would add to the interest with which it was regarded. The deposit is composed of an excellent brown ore. Coal seams underlie it, and outcrop in the neighboring valleys, while good limestone can be obtained within forty miles. So it is not surprising that the first Iron Works should have been erected in this vicinity.

The land upon which the ore occurs was first applied for in the names of John Neale, Samuel Holmes, and William Burton, in the year 1852. These men formed a syndicate, erected a small blast furnace, and imported skilled workmen from England. The works were opened by Governor Sir Charles Fitzroy; smelting operations were carried on at intervals during two or three years, but were eventually discontinued on account of the venture not proving profitable.

In 1859 the works were leased by Messrs. Latton, Enoch Hughes and William Hughes. They built the blast furnace which is now standing, and erected blowing engines. The furnace is constructed of Hawkesbury sandstone, is forty-nine feet high, and the interior diameter at the bosh is fourteen feet. Anthracite coal, obtained from the Nattai Valley, and charcoal were used as fuel. Smelting operations did not proceed satisfactorily and very little iron was produced.

Fig. 2—The old Fitzroy Iron Works, near Mittagong, New South Wales.

During the years 1864, 1865 and 1866, the works were managed by a Mr. Hampshire, and under his management considerable progress was made. He introduced the hot blast and erected puddling furnaces and rolling mills. Mr. Hampshire succeeded in making a quantity of iron and many castings were sent away from the works; amongst the latter were included the cylinders for the Gundagai Bridge, and the girders for Vickery's Chambers, Pitt Street, Sydney.

About the year 1875 the works were taken over by the Fitzroy Bessemer Steel and Haematite Iron and Coal Company, and the management was given to a Mr. David Smith, who, coming from England, brought with him smelters and other skilled workmen. Mr. Smith caused a tramway to be laid down between the works and the coal mines in the Nattai Valley. However, very little iron seems to have been made until the management passed into the hands of Mr. David Lawson, in 1876. Mr. Lawson recognizing the inferior quality of the anthracite

Fig. 3—The Eskbank Iron Works, Lithgow, in 1880.

occurring in the Nattai Valley, obtained his coal and coke from Bulli and Lithgow. During a period commencing in February, 1876, and ending in March, 1877, 3,242 tons of pig iron were produced.

The Lithgow (Eskbank) Iron Works. The foundation of the blast furnace was laid on New Year's Day, 1874. Smelting operations commenced in October, 1875, and were carried on intermittently for several years, about 22,000 tons of pig iron being produced. The ore used was partly clay band occurring in the district, and partly brown and magnetic ores obtained from New-

bridge and Blayney. The greater portion of the pig iron was converted upon the ground into castings, bars, angle iron, and iron rails. The large bed plate and the fly-wheel now in use at the works were both manufactured from iron produced from New South Wales ores. As the operations were not financially successful, smelting was discontinued after a few years, and the blast furnace was pulled down. After the cessation of smelting operations the Lithgow Works were for a short period carried on upon the co-operative system by a party of workmen, the rolling mills being chiefly employed in re-rolling old iron rails.

In 1885, the works were taken on lease by Mr. W. Sanford, and after that date considerable progress was made, and large quantities of scrap iron were worked up into bars, sheets, etc.: a sheet mill, a galvanizing plant, and machines for the manufacture of railway spikes were erected: also a Siemen's steel furnace was added to the works, and in this furnace steel was manufactured for the first time in the Colony.

Hoskins Iron & Steel Co., Ltd. (Owned and operated by Mr. C. H. Hoskins and members of his family, who furnish the following information):—

Mr. C. H. Hoskins purchased the Lithgow Iron Works from Mr. W. Sanford and took possession on January 1, 1908. The plant at Lithgow at that time was extremely antiquated and inefficient, with the exception of a new blast furnace which had recently been installed.

At the time of taking over this plant it consisted of the following:—One blast furnace with three stoves (making 700 tons per week), one 15-ton and two 4-ton basic new-form Siemen's furnaces, one 24″ mill, reversing by means of clutches, which had never been worked and was quite useless, one 18″ two-high pull-over mill, one 14″ muck bar mill, one 14″ two-high pull-over bar mill and one small 9″ three-high guide mill. With the exception of the blast furnace and the 18″ mill, both

Fig. 4—View of blast furnaces from the stove side, Lithgow Works, Hoskins Iron and Steel Company, Ltd.

Fig. 5—Front view of blast furnaces, showing 120 foot crane over pig beds, Lithgow Works, Hoskins Iron and Steel Company, Ltd.

of which have been considerably altered, the remainder of the entire plant has been torn down and removed, and is being replaced with a thoroughly modern plant. At the time of taking over this plant the main operation of these works was the rolling of wrought iron piles and puddled bar from eight puddling furnaces which were then in existence. The present Company however decided to abandon the making and rolling of wrought iron and to concentrate on the production of steel.

The various plants operated by the Company are as follows:—The main iron and steel works are situated at Lithgow on the Blue Mountains at an elevation of 3,000 feet above sea level, and 96 miles west of Sydney. An Engineering and Cast Iron Pipe Works are situated at Sydney and at Rhodes, a suburb of Sydney. A colliery, comprising 5,000 acres of coal land, together with coking plant, is situated at Dapto, on the coast, 56 miles south of Sydney in the Southern coal field. The Company has recently purchased 400 acres of land on the coast at Port Kembla, 8 miles distant from the above colliery and coking plant, with a view to establishing a modern steel works to allow for future extensions whenever required.

One of the Directors has just returned from an extensive tour of England, United States and Canada, where he gathered information regarding the most modern iron and steel plants, in order that the new plant on the coast together with numerous alterations and extensions to the existing plant at Lithgow should be along the most modern lines.

The Company is practically self-supporting for all its raw materials, as it owns numerous iron ore properties in New South Wales and Tasmania, together with extensive coal properties and limestone deposits.

In addition to the above they also own several manganese ore properties, the ore being of very high quality, from which many thousands of tons of high-

grade ferro-manganese have been produced during the past five years.

The Works at Lithgow are situated in the heart of

Fig. 6—Another view of front of blast furnaces, Lithgow Works, Hoskins Iron and Steel Company, Ltd.

the Western Coalfield, the coal for use in the steel works going straight into the works from the mine, which is less than a quarter of a mile distant from the mills.

The Company is also opening up an additional coal

mine at Lithgow, 2 miles from the works, consisting of about 3,500 acres of good coking coal. This coal seam is 10 feet thick at a depth of 300 feet, 6 feet of which is good coal containing about 32% volatile matter and 8% of ash. The remaining 4 feet is inferior coal containing about 12% of ash and is used mainly for firing boilers.

The Company's coal property at Dapto consists of 5,000 acres of coal land containing 4 seams of coal, three of which contain good coal; the top seam, containing 8% ash, 27% volatile matter, makes a very strong coke for blast furnace work.

The Company holds numerous iron ore properties which together are estimated to contain between 80,000,000 and 100,000,000 tons of good ore. The ore for the present steel works at Lithgow is drawn from Tallawang, 100 miles northwest; Carcoar, 80 miles southwest; and Cadia, 100 miles southwest of Lithgow. The first mentioned ore is a magnetite containing 60% of iron, the latter two are red hematite containing 57 to 58% of iron. Numerous other deposits are also held about 100 miles southwest and south of Lithgow. The limestone for the Lithgow Works is obtained from the Company's own quarries, 25 miles west of the steel works. The manganese ore is obtained at Grenfell, 156 miles west of Lithgow. The whole of these supplies are brought by rail to Lithgow on the State Railways.

Numerous other ore deposits containing red hematite with about 58% of iron are held in New South Wales, to be used at the proposed steel works on the coast at Port Kembla.

There are also very extensive magnetite deposits in Tasmania from which ore will be shipped to the steel works at Port Kembla.

The Lithgow Steel Works consist of a coke oven plant of 95 Belgian-type, non-recovery ovens with a capacity of 1500 tons of coke per week. This supply of coke is augmented from a similar plant at Dapto. There are

two blast furnaces which have a combined capacity of 150,000 tons per annum. These are at present hand-filled, but it is expected will be enlarged and mechanically charged in the near future. Of the iron produced, approximately half is of foundry quality, the other half being sent direct in 30-ton ladles to the steel plant. The blast furnaces are blown with three Parsons' turbine

Fig. 7—General view of the steel works, Lithgow Works, Hoskins Iron and Steel Company, Ltd.

blowers, the largest of which has a capacity of 40,000 cubic feet per minute at 18 pounds pressure per square inch. The usual working pressure is about 10 pounds per square inch, and the blast temperature 1100° F. Owing to all the materials being low in sulphur no difficulty is experienced in making first class iron, both for foundry and steel-making purposes, the coke containing .65% sulphur.

The open-hearth shop consists of three modern basic open-hearth furnaces of 50 tons, 70 tons and 80 tons capacity, respectively. A fourth furnace is now being added, which also will have a capacity of 80 tons. The furnaces are charged by an overhead Slewing-type charger, and the steel ladles are handled by a 100-ton electric crane, which also handles the hot metal from the blast furnaces. (This crane is to be transferred at once to the charging side, and a crane of 150 tons capacity will take its place for handling the steel ladles.) The ingots at present are taken hot to the 28″ blooming and finishing mill which rolls blooms and billets of standard sizes below 8″ square. The blooming rolls are driven by a two-cylinder engine 42″x60″ developing approximately 5,000 H. P., the finishing mill being driven by a three-cylinder Davey engine 32″x42″. The capacity of this mill is 4,000 tons of billets per week, or a lesser tonnage on finished sections, but owing to lack of steel this mill is at present only operating one shift.

The bar mills consist at the present time of one 18″ two-high pull-over mill, one modern 10″ guide mill and one 9″ guide mill. The 10″ mill has just been installed in a very fine building 70 feet wide by 400 feet long, with provision for further extension when required. The 9″ mill is situated in a similar building alongside the 10″ mill and is at present under construction.

The works have their own engineering shops and foundries and most of the alterations and extensions to the plant are carried out in these departments. All classes of carbon steel are manufactured, including a large variety of spring steel, together with numerous special qualities for the manufacture of small arms as well as other specifications.

The Cast Iron Pipe and General Engineering Works are situated in Sydney and Rhodes, a suburb of Sydney, on the Parramatta River. These pipe plants are easily the largest in Australia, and the plant at Rhodes is along

the most modern lines and is claimed to be one of the finest plants for this class of work in the world. The capacity of the Cast Iron Pipe Works is 1500 tons per week, working one shift of 8¾ hours.

The Broken Hill Proprietary Co., Ltd.

The history of this Company, as told by Roy Bridges in the volume entitled "From Silver to Steel, or The

Fig. 8—Ironstone quarries of The Broken Hill Proprietary Company, Iron Knob, South Australia.

Romance of the Broken Hill Proprietary," forms very interesting reading.

According to this authority the Proprietary Company sprang from the first syndicate of seven on Mt. Gipps Station, Western New South Wales, and the succeeding Broken Hill Company of fourteen which in 1885 controlled the majority of that famous lode of the "Great Barrier Reef" called "Broken Hill." Within 34 years the Proprietary Mine in Broken Hill yielded 173,451,037 ounces of silver, 1,279,334 tons of lead, and 102,857 ounces of gold. It paid to its shareholders

$50,708,822 in cash dividends, $2,726,400 in cash bonuses, $2,764,800 in cash from the flotation of the British Broken Hill Proprietary Co., Ltd., $8,371,200 in shares in the companies floated from the parent Company,—a total of $64,571,222. In that period it distributed $64,073,088 in wages.

It developed wide markets in Europe for its silver and lead, and by the discovery of the "flotation process," converted a bank of 5½ million tons of unworkable sulphide tailings into an asset of the value of $150,000,000, based on the metal contents.

Fig. 9—Steam shovel at work on Iron Knob, South Australia.

It established its famous lead smelters and refinery in South Australia, The Port Pirie Works, and for flux obtained possession of the Iron Monarch and Iron Knob on the western shore of Spencer's Gulf in the same State.

The Company at that time was producing from its lead furnaces about 400 tons per day of lead-silver bullion, carrying a certain quantity of gold, and had therefore built up an important export trade of these metals, but no attempt was being made to utilize its

large deposits of iron ore, other than as flux for the lead smelters.

The imports of pig, rails, billets, bars, shapes, wire products and sheets during 1909 were valued at over $20,000,000.

About this time the Board of Directors began to consider the advisability of utilizing its large assets of iron ore for supplying the demand in the country for iron and steel products, and accordingly in 1911 they sent the General Manager, Mr. G. D. Delprat, to Europe and the United States to visit iron and steel works and obtain information to assist them in making a decision.

As a result, the writer was engaged to come to Australia and investigate the subject, and report to the Board on the advisability of undertaking the project.

At that time some 400,000 tons of ore of the following average analysis had been mined from the Iron Knob deposit for flux:—

Iron	67.94
Phosphorus	.052
Insolubles	1.75
Sulphur	trace

The original deposit called Iron Knob and Iron Monarch consists of two separate mountain masses of solid, almost pure, hematite, with varying percentages of manganese, the diamond drill showing that the surface ore is highest in manganese—in fact certain parts of the deposit contain as high as 10% manganese with 55% iron, while the bulk of the ore contains about 0.6% manganese, and there are certain parts of the deposit almost entirely free from this metal.

The ore is quarried from the side of the mountain, loaded with steam shovels on to skips which traverse an incline to loading bins, from whence a haul of 35 miles by rail over the Company's tracks delivers the ore to the crushing plant placed adjacent to large loading bins. The crushed ore from these bins is loaded into the ships

on a belt, at the rate of 1,000 tons per hour. From the point of shipment to the Port of Newcastle the distance is 1,200 miles, passing the cities of Adelaide and Melbourne. Returning, the ships deliver steel or coal to the cities named.

Coal Fields of Australia

The most important coal deposits of the country so far developed are located about the mouth of the

Fig. 10—Wharf with belt conveyor for loading iron ore into vessels, Spencers Gulf, South Australia.

Hunter River, Newcastle, New South Wales, and the upper seams of this deposit extend southward 60 miles under the city of Sydney, at a depth of 2,000 feet, and re-appear again at the surface about 45 miles south of Sydney, close to the coast at Bulli and Bellambi.

These two fields are estimated to contain 115,000,000,000 tons of available coal.

All this coal is of coking quality. It is rather high in phosphorus, and that of the upper seams of the northern field contains from 33% to 35% volatile matter, but the coke from the small coal, while low in sulphur, will

average about 18% in ash. The lower seams of the northern field are higher in volatile matter, up to 40%, are very low in ash, and in many places the seams are 15 feet thick of solid coal.

In the southern districts the coal will average 18% in volatile matter, is low in sulphur, and the ash in the coke from the small coal will average about 16%.

The coke made from the northern coal—particularly the Borehole seam,—is free burning, fairly hard, but quite friable; the average weight per cubic foot is 25 pounds, and it resembles very much the coke produced at the Clairton Works of the United States Steel Corporation. The coke from the southern district is very hard, dense, slow-burning; the average weight per cubic foot is 34 pounds, and on account of its resistance to breakage is widely used in the country in the lead and copper smelters; the rough handling the coke receives in bulk handling by water shipment simply reduces the large lumps of coke as they come from the retort or by-product ovens to a more suitable size for the furnaces, while the loss in breeze is not excessive.

The coal deposits of Victoria consist of large beds of lignite, but are only worked to a very small extent.

The only other State having large quantities of coal is Queensland, and the indications are that in coal deposits it is very richly endowed.

Newcastle Works

As the coke from the northern field of New South Wales was considered by the writer more suitable for use in iron blast furnaces, a site was chosen at the Port of Newcastle where a channel from the works to deep water could be secured to a depth of 25 feet at low tide. While the coal underlies the city and harbor of Newcastle, the average haul to all mines of the field is 15 miles.

The limestone for fluxing purposes is obtained from a very large deposit in Tasmania close to deep water,

and an occasional ore boat is despatched to this quarry to keep up the supply to the blast furnaces. This stone is a calcite, averaging about 6% in insoluble matter. A high-

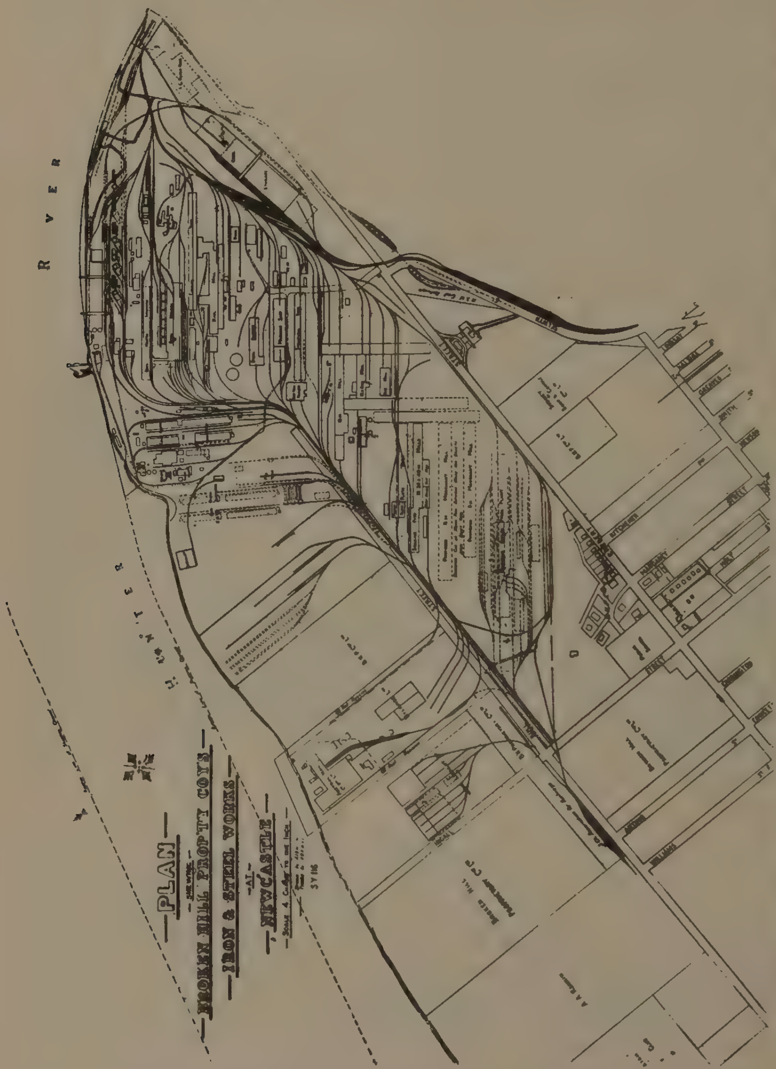


Fig. 11—Plan of Newcastle Works, The Broken Hill Proprietary Company, Ltd., Newcastle, N. S. W.

grade calcite stone containing less than 2% insoluble matter, for use in the open-hearth furnaces and the ferro-furnace, is obtained from quarries owned by the

Company at Taree and Attunga in the northern part of the State.

The works as originally planned were to consist of one 350-ton blast furnace, three 65-ton basic open-hearth furnaces, one 35″ blooming mill, and one 28″ rail and structural mill, with the necessary by-product ovens to supply coke for the blast furnace. The plans of the works were completed early in 1913, and the material ordered that year. Meanwhile, the Government of the State undertook to dredge the channel to the works, pumping the sand and silt on to the low-lying property forming the site chosen for the plant.

The first cargo of material for construction arrived January 1, 1914. Meanwhile, pile-driving and concrete laying of the foundations had been vigorously pushed, until the declaration of war stopped all construction work. This stoppage lasted only a few days, the Board of Directors deciding that the completion of the works would make Australia independent of outside sources of supply for the principal part of its steel requirements, and might thus render material assistance to the Allies in winning the war. Accordingly an organization was brought together as soon as possible, and construction work pushed on so that the blast furnace was lighted March 9, 1915, and the first steel was made April 9, the first ingot bloomed the same day, while rail rolling started April 24.

The formal opening of the works under the direction of the Governor General, Sir Ronald Munro Ferguson, took place June 2, 1915.

The starting of the works early in the war enabled the country to push on and complete the strategic line from Kalgoorlie in Western Australia, to Port Augusta at the head of Spencer's Gulf, thus connecting by rail Perth (the capital) and Fremantle (the port of shipment in Western Australia) with all the large cities of South Australia, Victoria, and New South Wales. In addition,

Fig. 12—View of part of the Newcastle Steel Works from the harbor.

Fig. 13—Another view of the Newcastle Steel Works, looking southeast.

The Broken Hill Proprietary Company furnished rails for South Africa, to replace lines torn up to supply equipment for France, also rails and munition bar to the British War Department, and rolled on its 35″ blooming mill 10,000 tons of ¼″ to 1″ plates for ship construction, as well as the joists and bulb angles for the frames of all the ships built under the direction of the Commonwealth Government in this country.

Fig. 14—Works Office, Newcastle Works, The Broken Hill Proprietary Company, Ltd.

Since the original installation was laid down at Newcastle, the works have been increased and now consist of the following plant:—

Coke Oven Department, with 224 Semet-Solvay by-product ovens of the recuperative type, arranged for recovery of tar, sulphate and benzol.

Blast Furnace Department, with 2 furnaces 85′x20′, 1 furnace 90′x20′, and 1 furnace 68′x12′, this latter being for the manufacture of ferro-manganese.

The ore yard is spanned by two Hoover & Mason bridge unloaders, equipped with 6-ton grab buckets, which deliver the ore and limestone from the skips to the stock pile, or into a 50-ton transfer car for distribution to each of the four blast furnaces. The molten basic pig iron is taken direct to the open-hearth, and the excess of metal poured into a pig machine which discharges into the open-hearth stock-yard. Foundry pig iron is poured over another pig machine equipped with a travelling gantry for handling the cold pig and stacking same according to analysis.

The Open Hearth Department consists of 7 basic furnaces of 65 tons rated capacity, but with hearths 33′6″x15′, and two 100-ton pit cranes, one 75 and one 60-ton hot metal cranes, and a 1000-ton mixer.

The Blooming Mill is provided with three 4-hole pit furnaces, a stripping crane, and 2 pit cranes. The mill is a 35″ geared Mackintosh & Hemphill design, with two high-pressure cylinders 66″x42″, the steam pressure being 150 lbs. at the engine. There are also two mechanical shears, one for cutting blooms and blanks going to the rail mill, the other for taking the billets from transfer beds and cutting this product for the market or for re-rolling in the 18″ merchant mill.

The Rail Mill consists of three strands of rolls in line, of 28″ pitch diameter, and equipped with two travelling tables and a stationary saw run. The rolls are driven by a double high-pressure reversing engine with cylinders 66″x42″, the steam pressure at the engine being 150 pounds. The engine is controlled from a pulpit in plain sight of the rolling operation, and while the engine is slowed down when the piece is introduced into the rolls, it is speeded up to 150 revolutions when the piece is in the finishing pass. The mill is equipped with two 60-ton travelling cranes, and a double set of housings, so that each strand of housings and rolls are lifted at one time and replaced with the other set with rolls and guides

Fig. 15—Blast furnaces, Newcastle Works, from the west side.

Fig. 16—View of blast furnaces, receiving and shipping wharves, Newcastle Works.

Fig. 17—Coke ovens and by-product plant, Newcastle Works.

Fig. 18—View of coal storage crane (200 feet span), Newcastle Works.

set. All blooms and blanks when received from the blooming mill are re-heated in two regenerative heating furnaces fired with coke oven gas. The product of the mill consists of tee rails from 45 pounds to 100 pounds, girder rails, angles, heavy rounds, channels and joists up to 15″, the largest size required to date.

This mill has never been supplied with sufficient steel to test its full capacity, as the blooming mill is required to do jobbing work and to supply the 18″ merchant train with billets.

Fig. 19—Open hearth, rail mill and shops, Newcastle Works.

The finishing department of the mill is provided with 3 hot beds, 4 rail presses, and ending machines, and each rail is ended to exact length after straightening, the standard length of 80, 90, and 100 pound rails being 40 feet. The rail stock-yard is 75 feet wide and 1,000 feet long, and is provided with two 25-ton cranes equipped with magnets for stocking and loading purposes. Along one side of the mill is a 50-foot lean-to, containing the roll shop, equipped with a 20-ton crane, and an extension to the crane runway forms the roll yard.

Merchant Mills. This department consists of one 18″ mill equipped with 4 travelling tables and 2 continuous

Fig. 20—Open hearth steel furnaces, Newcastle Works, The Broken Hill Proprietary Company, Ltd.

Fig. 21—Blooming Mill, Newcastle Works, The Broken Hill Proprietary Company, Ltd.

billet heating furnaces, also finishing equipment and hot beds to take care of light rails, heavy merchant bar, fishplates, and billets; one 12″ mill and one 8″ mill are installed in a separate building, each equipped with continuous heating furnaces and hand hotbeds. There is also adjoining the merchant mills a double-strand Morgan continuous rod mill, arranged to be fed from the billet yard receiving the product from the 18″ mill.

Shops. Mechanical repairs and considerable construction work are economically handled by a large and well-equipped machine shop, and a steel foundry equipped with a 20-ton acid open-hearth furnace; a direct metal foundry for the manufacture of ingot moulds and heavy castings with hot metal from the blast furnaces; and suitable shops for the other mechanical trades.

Power House. The power for the works is obtained from a D. C. station located close to the blooming and rail mill, and supplied with steam from an extension of the rail mill boilers.

Production. The problem of the production of a satisfactory grade of basic steel for all requirements has been worked out to meet local conditions in Australia, and some of the methods and results obtained form a part of the history of the development of the iron and steel industry in this country.

Starting from the production of the coke, as the fuel produced was of a friable nature it became necessary to exercise unusual care in the delivery of coke to the blast furnaces, and accordingly inclined coke benches with screen bars were installed at the coke ovens, the coke from these benches being delivered in narrow gauge trucks to the blast furnace stock-yard, each truck containing a skip load and handled so that it discharges its contents direct into the skip. This reduces the loss in coke breeze to 5%, and is an important factor in maintaining regular furnace work.

In the production of pig iron, arrangements were made at the quarries and at the mine so that a finely crushed ore is delivered to the stock-yard at the furnaces, and a suitable crushed limestone as flux. As the ore and coke contain a high percentage of alumina, a certain quantity of silica rock and open-hearth slag is used to increase the slag volume to what is required for easy smelting conditions. The large furnaces are equipped with concrete ore bins, single skips and the Baker and Neumann rotary distributors. The production

Fig. 22—Rod Mill and Merchant Mills, Newcastle Works.

of the furnaces has exceeded the original estimates, so that there has been no difficulty in obtaining from the three larger furnaces a regular output of 3,000 tons of basic pig iron per week from each stack, without forcing. This has been accomplished with a 13′ hearth, and gives prospect that with the adoption of larger dimensions a very much larger production per furnace will result.

In the production of steel in the basic furnaces, the scrap supply in Australia being a negligible quantity, the problem encountered was that of operating the furnaces on a mixture of 80% pig iron and only the scrap made in the works. This situation has been very satisfactorily

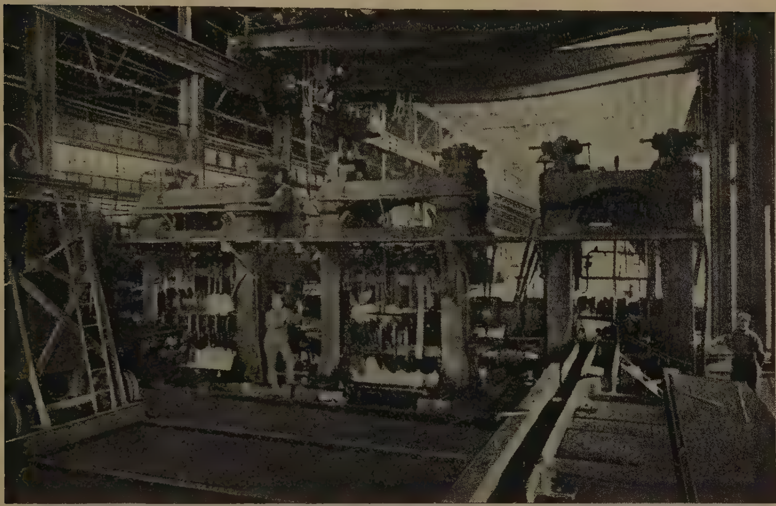


Fig. 23—Rail Mill, Newcastle Works, The Broken Hill Proprietary Company, Ltd.

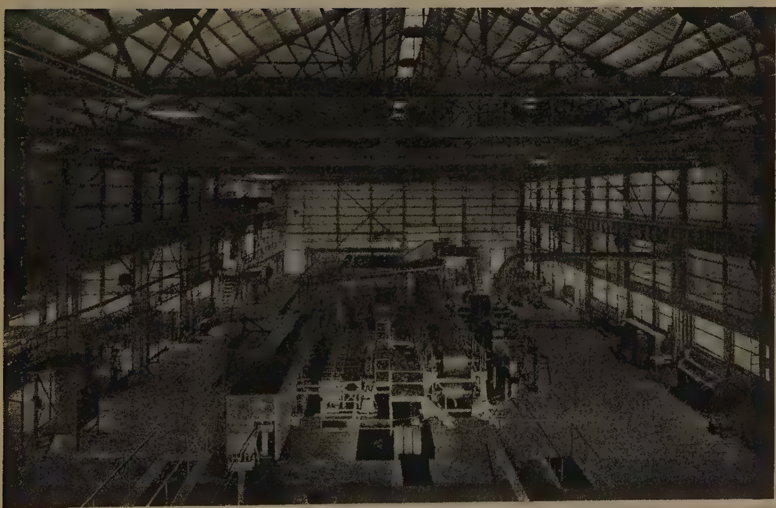


Fig. 24—Rod Mill, Newcastle Works, The Broken Hill Proprietary Company, Ltd.

met by a modification of design of the open-hearth furnaces, so that whereas at the start the average time for producing a heat of steel was approximately 12 hours, it has been reduced to less than 7½ hours (half-yearly average), with an occasional heat produced in 3 hours 50 minutes. It has therefore been possible to produce steel at the rate of 36,000 tons per month, with an occasional week of 11,000 tons.

The rail mill as now equipped, has a capacity of 1,000 tons per day, of 80 pound rails, but by driving the intermediate and finishing strands by a separate engine or motor, and adding additional tables, the capacity of the mill may be doubled.

The quality of the steel has met every requirement most satisfactorily, from the manufacture of railroad tires, locomotive forgings, to rails, structural work, ship and boiler plate, sheets and wire. Rail specifications particularly, adopted in this country by Government controlled railways, are exceedingly rigid, requiring a drop test from every ingot, the test piece being cut from the top end of the first rail and in case of 80 pound rails subjected to a drop of 20 feet with a gross ton tup, with very narrow limits in section variations, the rolling operation being under the supervision of a large corps of Government inspectors. The laboratory equipment—both chemical and physical—and the chemical and metallurgical staff provided by the Company to meet this situation, have been most carefully chosen. In view of the requirements, the average recovery of 95% of accepted rails may be considered as a good indication of the quality of the steel produced.

To provide the works against possible stoppages due to holidays at the mines, a coal storage equipment has been installed, consisting of a travelling bridge of 200′ span, equipped with a combination trolley, one end provided with a Hoover & Mason grab, capable of lifting 5 tons of coal; the other end equipped with hoisting

drums so that the 4-wheeled coal trucks from the mines containing 10 tons of coal are lifted bodily and discharge their contents on the stock pile. The reclaiming of the coal and its delivery into 50-ton steel cars of American type is done with the grab bucket.

The plant is also equipped with ample wharf area for receiving supplies and for lifting the products into steamers, as a large percentage of the output of the plant is despatched by water.

Plans have been prepared and a large part of the equipment purchased for the following extensions to the works:—Additional open-hearth furnaces to permit the conversion of 550,000 tons of basic pig iron into steel; a 40″ electrically driven blooming mill supplying a 24″ and 18″ Morgan continuous billet and sheet bar mill; a Morgan 10″ continuous merchant mill. In order to supply electric power for these extensions of the plant, a power house is to be built where the surplus gas from the blast furnaces can be utilized to supply the power required.

Subsidiary Industries

The Austral Nail Co. Pty., Ltd., of Melbourne, had been manufacturing nails and barb wire in Melbourne for thirty years and had been manufacturing wire from American and Continental rods from 1911 until 1918, at which latter date they commenced to draw their raw material supplies from the Broken Hill Proprietary Company's steel works in Newcastle. It was decided early in 1918 to erect a large modern wire mill in Newcastle adjacent to the steel works and to close down the Melbourne mill. The erection of the plant commenced during April, 1918, and operations started on September 26 of that year on a limited output. In January, 1920, regular production was commenced and during the first twelve months' operations 45,000 tons of wire were drawn.

Early in 1921, Rylands Brothers, Ltd., of Warrington, England, decided to establish Australian works, primarily for the manufacture of wire netting and the finer wire products. Following on this an amalgamation of the Austral Nail Co. Pty., Ltd., and the Australian interests of Rylands Brothers, Ltd., was effected under the name of Rylands Brothers (Australia), Ltd. Prior to the amalgamation the Austral Nail Co. Pty., Ltd., had been rapidly extending their mill for the production of all classes of plain wire and the manufacture of spring, coppered and galvanized wires, nails and barb wire, while Rylands Brothers, Ltd., made large shipments to

Fig. 25—Auxiliary industries, Sheet Mills and Wire Works, Newcastle, New South Wales.

Australia of the necessary equipment for a complete netting plant. A portion of this is now in operation and the remainder will be running by March of this year. This plant, together with the existing machinery, will enable Messrs. Rylands Brothers to manufacture from 75,000 to 100,000 tons of mixed wire products per annum, this range of manufacture running from heavy fence wire down to the very finest gauges of tinned wires used for such purposes as mattress making, etc. They are also in a position to manufacture high-grade high-carbon wires such as are commonly used for rope making, etc.

Apart from these wire products the netting works

recently established will be capable of turning out from 10,000 to 20,000 miles of netting per year.

The whole works is designed on the most modern lines and will be able to deal with all the wire and wire netting requirements of the Australian market.

Lysaght's Newcastle Works, Ltd.

These works have been erected for the manufacture of black sheets, galvanized plain sheets and corrugated sheets, and no expense has been spared to make the plant modern in every respect, and equal to any in the world. Foundations have been put in for eight sheet mills, two of which are now in operation, and local labor has been drafted to learn the system, so that other mills may be started up. The mills are driven from a direct current motor of 1300 KW. coupled to which is a fly-wheel of thirty-four feet diameter, weighing 160 tons. The power is purchased from the Newcastle Electric Supply Department, who supply at 6600 volts, 3 phase, 25 cycles. Transformers have been installed to reduce the voltage to 375 volts, for which the rotary converter was designed, and here the current is converted from alternating to direct current. The whole of the electrical apparatus for the mill motor was manufactured by the Metropolitan-Vickers Company of Manchester, England. The close annealing furnace is of the continuous type, is gas-fired and will deal with 500 tons of sheets per week. In the pickling department a machine has been installed so that the picklers are not continually in contact with the acid fumes. The galvanizing department has been designed to accommodate three pots, one of which is in operation, and the finished galvanized sheet is of excellent quality, and exceeds expectations. The corrugating machine is of the rotary type, and will deal with 450 tons per week. Finished black sheets, galvan-

ized flats or corrugated sheets can now be supplied in half ton and five cwt. cases, or in bundles of two cwts.

The market for iron and steel products in Australia is a growing one. The vast areas used as pasture lands for cattle and sheep furnish a large market for fencing material. This is augmented over what would obtain in pastoral areas in other countries, on account of the rabbit pest, which makes it necessary to fence off sections used for wheat raising and other farm products.

It has been found necessary to build fences of rabbit-proof netting to prevent the migration of this pest, and it has been estimated that the market for wire products alone in this country would, in normal times, amount to 100,000 tons per year, a fairly large consumption when it is considered that the population of the country is less than that of the City of New York.

The demand for steel corrugated galvanized sheeting was over 100,000 tons per year before the war, and as it is almost universally used for the roof of the ordinary dwelling house, the market grows as the population increases.

The country is much in need of important railroad extensions to take care of the present rural population, as well as the immigrants now finding homes on this country's fertile areas. This means an increasing demand for steel rails and railroad equipment.

One of the great lessons of the war is the importance of making the country self-contained as far as supplies for the maintenance of the high standard of living established here are concerned, and also to take care of the future development of this Colony which offers so many inducements to white settlers, and the Government takes a keen interest in home industries—therefore the future of the iron and steel business in Australia gives every encouragement to the promoters of the enterprise.

The future of Australia is safe in the hands of its people and its rapid growth is assured. The iron and steel industry, already firmly established, will find ample inducement for extension in taking care of the future requirements of this new continent.

Judge Gary: The next paper is The Relation of the Doctor to the Steel Plant, by Dr. Loyal A. Shoudy, chief surgeon, Bethlehem Steel Corporation, Bethlehem, Pa.

THE RELATION OF THE DOCTOR TO THE STEEL PLANT

Loyal A. Shoudy

Chief Surgeon, Bethlehem Steel Corporation, Bethlehem, Pa.

I am to talk to you on the relation of the doctor to the steel plant. I know that you have your ideas as to how the doctor should function—only when called. Well, I have been called this morning and I want to divert your attention to that part of the doctor's work which is after all really worth while, and a part which, though it has no scientific bearing, makes life just a little easier for the worker, because he finds a place apart from the wheels and rolls, where someone is interested in him as he presents himself.

Mr. Williams, Mr. Farrell, Mr. Campbell, Mr. Schwab, you know the worker of the blast furnace, of the open-hearth, the pot-pullers, the riggers, the rail mill men, moulders—to you the real men of the steel industry—and I want to introduce to you, and I want you to become better acquainted with a later addition to your steel family, the foreman of your human repair shop, the doctor in your industry.

I am not to tell you the detailed advantages of physical examination, not to tell you the value of iodine or Dakin's solution, not to tell you the value of Thomas splint and fracture box; but to bring to your attention a phase of the doctor's work which appeals to me and the part of this work that makes the job worth while.

For many years it has been the custom in mines and plants to have available a group of men whose duty it is to be on hand when "something goes wrong" or a breakdown occurs, commonly known as the "monkey

wrench gang,'' the ''bull gang'' or the ''repair gang.'' They may come from the electrical department, from the mechanical department or any combination, it matters not because their function is the same—to repair. And these men on these gangs are generally so placed because they are good, quick and thinking workers. Men who can ''fix up'' the broken machine and get the works going so as not to interfere with production.

Now, men, I want you to know that the doctor in the plant runs a repair shop. He and his ''gang'' are repairmen, repairmen for the human machine.

I have been a steel worker for seven years, and I have watched mines and labor many years. I have seen wonderful plants built, cranes placed, engines placed, machines placed, the utmost of engineering skill used in designing and placing and all to the end of an efficient producing plant.

From the manager's point of view, he has a wonderful mechanical equipment. But, men, how much thought has been given to the real *running* of those machines? How much thought to the real guidance that production may reach the desired peak?

From the engineer's standpoint, from the architect's standpoint, all is well—but—and I ask you to consider, how much thought has been given to the *real* men who are to man those machines? Have your engineers looked them over? Have you seen to it that these machines are in good working order? If you look them over, do you place them accordingly? Men, the greatest raw product that comes to your plant, the greatest machine you purchase, is the *man,* the human machine. Do you treat him as such?

The doctor as a steel worker is comparatively a new institution. The doctor as the old type company doctor, the type whose duty it was to care for those maimed, is not new. In days past his work did not include what is now termed medical supervision. It is not my intent to go into the history of ''the company doctor'' but

rather to talk with you about my idea as to how he should function and his relation to the plant.

A few years ago I know that many of you doubted the wisdom of admitting a doctor to your steel family, and I know that the doctor has had to prove his right to be included in your family. You have always looked upon the doctor as someone apart from real work and have never considered him as being able to help in the manufacture of steel.

The doctor's repair shop must be a place where the injured men are glad to go. It must be so conducted that the men will feel confident that they will receive the best of care.

"The all day medical repair shop is a great melting pot for human experience. Here the virtues, as well as the weaknesses of men, are reflected. The right man in charge becomes both priest and physician, confessor and adviser. How necessary, therefore, that one secure a man not only of high professional attainments, but one of broad social vision. A cheap doctor, like a cheap machine, will produce a cheap result and no man will recognize that cheapness sooner than your workman."

Now when you men build an open-hearth, a rail mill, you build the best, you equip with the best, you give your superintendent the best of working facilities and expect him to produce. Let me ask you to so equip your doctor; you cannot rightfully expect him to show results if you only half-way equip him. You own the blast furnace, the open-hearth, the rail mill; why not own or control the doctor's workshop, the hospital, or at least a part sufficient for your needs, and equip it according to your needs? An industrial hospital, properly handled by men understanding industry, should prove of untold value in developing "good will" between the men and the plant.

You would not think of employing an open-hearth superintendent on part time, why employ a part-time doctor. You need his undivided thought and attention just as much as you need the open-hearth superinten-

dent's time. Select the right man and pay him, make him feel he is a part of your steel organization and let him be proud of his position. Medical work is not a charity, it should never be considered as a charity or welfare, it is a part of your plant, a part of your production and helps in your profits in proportion to how you develop and use it.

Ere long you will be called upon to define and compensate occupational disease. Why not prevent? You conduct laboratories of steel research, why not clinics of health research? Why not make men, as well as steel?

The conditions under which the doctor works and the things he does are important; but what he is, his sympathy for men, and his insight into the understanding of their problems, these are the things which are sure to reflect credit upon him and his profession.

Let me ask you to consider your medical service to your men; you now limit your work to accidents, when sickness causes you the greatest loss of time. Why not prevent sickness? Why not have a complete medical service with the best of medical advice? The industrial doctor learns the language of the shop, he has a common bond with the man. He knows the man and his job.

You shy at physical examination; in some states it must be done in some form, in order to protect you from buying a defective machine. I believe that some day you will agree and find it a profitable plan to examine all the machines you purchase; and profitable for you to keep these machines in good repair; and profitable to place them according to the work they can do.

Periodical reexamination will keep your men fit. Use the doctor's repair shop, because many times repairs can be made; but it is hard to rebuild the human machine. When the man once knows that you are interested in his health and are sincere in helping him, he will more than welcome your plan. Fitting the man to the job and not the job to the man, should be the work of the plant doctor. Certain men will produce more in certain lines and when

the foreman once learns that the doctor is a real help, he will be for him. The fitting of men to the job is a big problem and can only be solved by the cooperation of the employment manager, the doctor and the foreman.

I believe Mr. Schwab is responsible for the phrase "work with" not work for. If any man should "work with," it is the doctor. He works with the men, cheerfully, carefully, ably, and cares for the small wounds in the same thorough manner as the large ones. He never misses an opportunity to talk to the men about their jobs and their health. He teaches them to appreciate that health is the rightful heritage of every man and woman—the greatest gift of life—greater even than youth, for it lasts when youth is gone. Yet, great as it is, too often this wonderful gift is not properly appreciated until it is lost. It is through good health that we enjoy life at its fullest and best.

From the operative standpoint, you view the foreman as the keyman for production. The doctor and the foremen must be friends and coworkers. When talking to foremen, I always drive home the importance of their position; that the reason they are selected is because they are leaders of men, and that if they are to be good foremen, they must be *for* men.

They should understand the doctor and work with him, and know that when a man in their gang is not up to the mark, they should look him over, talk to him, and, if he needs repairs, send him to the doctor.

Not long since, a foreman called me up and said, "Doc, we have a fellow down here who coughs too much. We're afraid he has the con." I said, "Send him up." The man came; we examined him and found that he did have tuberculosis. Here was one man with tuberculosis, working with others—a possible source of infection to them all. Innocent in himself. Thought he had a cold. Contrast the cost of periodical examination with the relief cost. Contrast what could have been done for this man in early diagnosis, with his present condition. In this

case we advised with the man and he was only too glad to go to a sanitarium.

Another instance, when a man came in and wanted a change in job. We called the foreman and he said, "No, Doc, we think that fellow is a piker, he always wants an easy job." Now I know that there are pikers, men who can always find some new ache or pain, and willing to swear that the jobs they are doing are the cause. The doctor must carefully examine the man and the thing to be guarded against is permitting such men to blind you to the real ills of the honest man.

Foremen and superintendents in large plants are first of all concerned with production, but I want to tell you that I have yet to find in our plant a superintendent or foreman, who at heart was not interested in his men. The secret is to awaken this interest, to stimulate it. Once working, its worth is more than all the relief and compensation you can pay. If the worker knows that his boss thinks of him in time of injury or need, if the boss calls at his home in sickness or at the hospital, the feeling, the resultant effect on that man, his feeling for his job and for his boss cannot be expressed. And it is a part of the doctor's work to stimulate this and bring it about. Foremen are good at heart, only they need a heart stimulant now and then.

It takes time to change and to educate men. The gangs are so large, the class of men so varied that to the average foreman the individual is lost, the name never known. It's the work to be done and damn you, do it. The average foreman does not know, feel or care for Petro or Mike, he does not know that Tony has a sick wife and baby. Tony is injured, crushed hand and leg; he meets the doctor. "Mr. Doctor, my baby, my baby, no got milk, no got eat; my wife, she no got eat, me no more good, no more work, Mr. Doctor, you do something." And men, if your doctor is right, here begins Tony's introduction to the foreman and to the plant. "Sent to the hospital" the wife is told; taken to the hospital to see

him to assure her he is still her living Tony. Tony is cared for surgically, placed in a clean bed; the nurse smiles—everything is pleasant.

At the plant, from the doctor's office goes a note or telephone to the foreman that Tony Wasco's condition is good. Tony's department superintendent is told, and next week this goes again. The superintendent wonders who Tony Wasco is—"Oh, yes, that wop who has his leg broken." Tony's buddies drop in to see Mr. Doctor and learn that Tony is doing fine.

At the hospital, Tony is really Tony, not a case. He is cared for by a Company surgeon who talks his language and knows his will, a real man cared for at Company expense in a cheerful room with pleasant surroundings, wife treated with consideration and allowed to see him. Tony, through the doctor, is given messages about the plant. The foreman receives notes as to Tony's progress and to him Tony becomes a real human, a man what was.

The visiting nurse calls, sees that milk, etc., are there for the baby and wife.

At the hospital, through kind handling, through proper surgical care, through a process of making over, Tony is supplied with artificial hand and leg and taught to use them before he leaves, taught a new job where he can make a living. He has been recalled, saved from the human scrap heap and becomes a real member of your family, with a feeling for the company that you cannot express.

A note goes to the department, to the foreman that Tony is discharged from the hospital, and later that Tony will return to work. And Tony returns, the foreman greets him, and he is for the first time Tony Wasco to that foreman.

Men, there are many Tonys in the steel industry and there are many foremen who need to know that he is in their gang.

And, men, from a company liability standpoint, this

broken leg becomes a company asset. The doctor becomes more than a repairman to human machines, he becomes a teacher, he leads the foreman to see the needs of his men, shows him that coughs and ruptures are capable of being repaired, stimulates in him a pride in having a good healthy gang of men and that the condition of his men reflects on him, because good men, mentally and physically, satisfied under his leadership, will do more and better work.

Accidents of some sort will always happen. The Safety Engineer has done much to lessen their number and severity. The doctor and the safety engineer must work "hand in hand."

From the doctor's talk with the injured man he learns many facts which are invaluable in the work of prevention. The cause may be in the man himself.

In days gone by we were wasteful of much material that is now saved. Economic conditions have wrought changes—now we save—the scrap heap is worked over. New products from by-products. There are economic reasons for the presence of the doctor in the plant, and with some employers these reasons outweigh all others. But they should never be the reason uppermost in the mind of the physician himself.

You should select your doctor with as much care as you select your superintendent or general manager. Select a doctor who has a high idea of the importance of his work. Select a doctor who has a real feeling for his fellowman and an understanding and vision of men and work. "He must be far more than a doctor of bodily ills and injuries. Besides being able to replace dislocated bones, he must be able to readjust human relations that are out of joint." The doctor who does not see that his profession leads beyond the care of the bodies of men into their moral and mental health, is not living up to his opportunity and duty, and especially is this true of the industrial doctor.

When I became a steel worker, I had a vision of my job, from my days spent around a mine watching the old idea of treatment and handling of men. I saw an opportunity for the doctor, a vision of what a real doctor could do for men, and I came to Bethlehem against the advice of my teacher, because I saw what he did not.

Early in my experience, the plant was so busy that no one paid much attention to the doctor. I was discouraged. On a visit to Philadelphia, I talked to my former teacher, and he asked me, "Well, how are you and Charley Schwab getting along?" "Well," I said, "I never see Charley Schwab, he doesn't know that I am in the plant." "Doesn't know you are in the plant? You go back to Bethlehem, take off your coat, pitch in, and if he doesn't know you are there by January, tell him to go to."

Men, this helped my vision and I saw anew my idea of the doctor in industry. I returned to Bethlehem and not long after I met Mr. Grace, and told him that it was my aim to give Bethlehem a Medical Department of which he could be as proud as he was of his armor plate, rails and guns. I felt that I was a steel worker, a part of the Bethlehem Plant. I came shortly after the "strike" and I was much impressed one day in talking to one of the old timers, a man who had been there in the time of John Fritz, who knew the iron game from all angles, a man who had worked with the masters. He said to me, "It's all wrong, Doc, it's all wrong, the men don't understand. When we all knew one another, this never happened. We're too big now and these young fellows don't know the boss, the master." And I didn't know Charley Schwab—the master.

"They don't understand." " 'Twas not like this in the old days, we knew the boss." These sayings of this old worker, his smile when he told me that he knew the boss, gave me an idea, a thought that somewhere we must find a substitute for the valuable relation of "master and man," that somewhere we must find some means of establishing new points of contact between men and boss, cap-

ital and labor, and it occurred to me that the doctor could be one of those points. From that day the Bethlehem Plant became my ''family practice,'' and I set about to make good as their doctor.

I believe that to no other man is given as great an opportunity to promote a better mutual understanding and relationship between employer and employee, as is given the doctor. The doctor in the plant should understand the workings of the plant, he must at all times work in harmony and cooperation with the various departments of the plant. He must understand men.

The steel industry has become so large, the number of men employed so great, that the employer sees the worker only in mass. The plant doctor—''his vision must be so clear, his sympathy so great, his sense of justice and fair play so keen, that however great the mass, he never loses sight of the individual.'' It doesn't take long for the plant to get wise as to what kind of a ''guy the Doc is.'' And your influence with the men will be as the kind of a ''guy'' you really are with the men.

Sometimes a man is unhappy for psychological reasons. The relations between him and the men about him are not congenial; the relations between him and his foreman are a constant source of irritation. The doctor knows that right mental conditions are just as important for the welfare and efficiency of a man, and that they have as much to do with output and profits, if viewed from the employer's point of view, and are deserving of as much attention, as physical conditions. You know mental ailments need treatment. Harsh words, sarcasm from a foreman or superintendent, give to the doctor his hardest jobs. Fears of all kinds, discontent, lack of a living wage, worry over sickness or trouble at home, worry over debts, over a love affair, over bad habits, and innumerable other stimuli for mental and physical depression are daily arising to undermine the health of employees, and it is as essential to remove these conditions as it is to tie up a cut finger.

Men, sickness and injuries are company liabilities, the right doctor with the right surroundings can turn them to company assets, and assets that you cannot measure in dollars and cents.

Worry over the job? You men in higher positions do it, and you break and you need to be looked over now and then. You have your troubles in wielding the large organization, you are not free from the cares of the day. But you do neglect yourselves. You need to be looked over now and then, you need to visit the doctor's repair shop, your carburetor needs adjusting. Men are prone to neglect themselves and at times will become so absorbed in the making of a living, in supplying the family needs, that they do not give proper care to their bodily needs.

Man is a machine—human as against mechanical. Iron or steel will not stand up under constant use, neither will man; he must be oiled and repaired occasionally, his habits changed at times and steered into another track. This he will not do of himself until the breakdown comes and then in most cases it is too late. As a result, through impaired health we have inefficiency—a liability to industry, the family and the community.

Industrial ill health and inefficiency are due to—

(a) Lack of proper ventilation—gases, fumes.
(b) Lack of proper lighting—eye strain.
(c) Necessity for change of occupation due to loss in sight, lung trouble, bodily injury or disease.
(d) Improper sanitation—drinking water.
(e) Treatment boils, occupational skin diseases, headaches, stomach, etc.
(f) Lack of periodical examination of men.
(g) Lack of consultation, prescription and advice.

The doctor should anticipate and remove the causes of ill health, either in the environment or in the human machine. Preventive medicine and the doctor's advice

are surely as important and warrant as much attention as we are giving to accident prevention from the educational and mechanical standpoint; and especially so when many accidents are due to the ill health of the individual.

Good will is essential to competent medical supervision. The plant doctor finds himself many times in a position in which he can bring both foreman, superintendent (employer) and the man (employee) to a better understanding of each other. "While all this is not a function of medicine, listening to other folks' troubles has become an obligation to physicians, whether in the home or the factory. It is a tribute which the whole world pays the physician. The plant doctor should betray no confidences. He must at all times be fair. His position as advisor to the employer and 'big brother to the employees,' although delicate, has opportunities which he must recognize in order to succeed as a plant doctor."

You know there are times in the lives of all men when things go wrong, times when we need a friend, when you feel that you "just must" talk things over with someone; this happens to you, it happens to the lowest man in your plant. Things break badly for him, the same as for you. There are times when a cheerful word means more to a man than you can tell.

> The glad-to-see-you treatment is great for human ills,
> 'Tis better than prescriptions and a multitude of pills,
> Today a man may grumble, and feel downcast and blue,
> The glad-to-see-you treatment will make him smile anew.
> A man may feel depressed, resolved to quit the fight,
> Your smile and "glad-to-see-you" may cheer and set him right.

Dean Marquis has said that corporations have no souls. If this be true of corporations which have included a physician in their organization, then it is the fault of the physician, for it is his duty to put a soul into a corporation. Now the steel family is a big one and one small doctor is not going to change time worn ideas, but if he keeps pegging away and sticks to his purpose, and is sincere and right—a man with ideals and courage —he is bound to make his presence felt and you are all going to help him.

Let me bring to you these points:

1. The success of industry in the broadest sense can be measured by the degree of understanding and good will attained between management and men.

The doctor is a promoter of good will.

2. The human ills of industry are mainly due to lack of points of contact between the man and the master.

The doctor is a point of contact.

3. The deepest and most lasting form of gratitude is given to him who relieves the sick or injured of their pain and consoles them in their hour of trouble.

The industrial doctor, of the proper type, is the most potent individual force in industry if empowered to care for the human machine while subject to the occupational environment on the job.

Just why the doctor is this man I am sure I cannot tell; may be, perhaps, it follows that from habit, when you consult a doctor you tell all. He must know all to help you.

Then again mental and physical illness need a doctor. It is a frame of mind. It is the doctor's business and after all it is but the natural outcome of training handed down.

In time of trouble you look for help, and the worker does not look upon the doctor as a steel man, but as a helper for his bodily ills, a friend who understands, and the value of that friendship is according as man to man the worker and the doctor understand.

JUDGE GARY: I am sure we have been very much interested and benefited by the able address of Dr. Shoudy, and we feel very grateful to him. Perhaps he minimized to some extent the work which is being done by many of the corporations or concerns in the line of his suggestions.

We will now listen to a paper on Industrial Housing, by C. L. Wooldridge, general superintendent, Carnegie Land Company, Pittsburgh, Pa.

INDUSTRIAL HOUSING

C. L. Wooldridge

General Superintendent, Carnegie Land Company, Pittsburgh, Pa.

It is with some feeling of diffidence that I have prepared this paper presenting to you some of the broad aspects of industrial housing, because every member of the American Iron and Steel Institute is probably familiar with and has had more or less experience in the subject. I will try, however, to express some of the fundamentals at least in a new way. It will be necessary to review very briefly some of the history which, in this country, preceded and led up to the movement called "Industrial Housing."

In the very beginning, most manufacturers who built houses for their workmen did so not because they felt that such a project would increase their earnings or the employes' efficiency, but solely because there existed a housing shortage and they could not get the necessary help to operate their plants unless they provided a place for the men to live. For the same reason, many companies, in isolated districts, were compelled to operate stores where the employes could purchase the necessities of life. It was not then generally considered that an average, normal workman had other instincts than that of working and the making of a home. His instincts for social life, recreation, education, and religion were usually left to develop and find expression without any thought or attention from his employer.

At about this same period, some employers began to improve the working conditions in their plants. They found it was easier to get men and hold them if their plants were clean and light, had decent toilet facilities, and were made as safe as possible. As this evolution in

the working conditions of the plant took place, it was found that not only the turnover was less expensive, but the employes' efficiency was actually increased, so that today every modern plant has its Department of Safety, Sanitation and Welfare, which has probably found its most advanced expression in the steel industry.

Do not misunderstand me in thinking that I in any degree discount or disparage the employers' humanitarian motives in this movement, for they have been of tremendous influence and no such evolution could be entirely successful if such were not the case. I think, however, it is beyond dispute that up to the beginning of the present century most manufacturers built houses because by so doing they more easily attracted the most and best workmen. In other words, they did what they thought would appeal to the workman as an individual and did not primarily consider the workman's family.

Unconsciously perhaps, but certainly very effectively, the iron and steel industry for many years has been dealing with the family unit. Our playgrounds, club houses, community houses, athletic fields, visiting nurses, picnics, baseball games, and band concerts are all matters concerning the family rather than the individual.

And so we have gradually come to consider that the term "Industrial Housing" means not merely the providing of a shelter for the family, but it comprehends stores, schools, churches, parks, recreation fields, playgrounds, and other places of amusement. In addition to these, there must be provided complete utilities so that the family is not only sheltered in comfort and decency but has the means of communicating socially with other families and may pass easily and quickly to and from work. I would not advocate that the employer provide all of these things for that would be paternalism in its worst form, but it is clearly to the employer's advantage to provide some of them, leaving the balance as a problem for the community. Furthermore, those things provided by the employer should be of such a character as to in-

Fig. 1—Group of Detached Houses, Wilson, Pa.

Fig. 2—Group of Detached Houses, McDonald, Ohio.

Fig. 3—Group of Row Type Houses, Wilson, Pa.

Fig. 4—Portion of Lincoln Row, negro section, Wilson, Pa.

sure that the standard of living is certainly not lowered by its example.

By far the most expensive and important part of industrial housing is the dwelling itself, and this also has passed through a startling evolution during the last thirty years. Thirty years ago, we built good, spacious, and very often beautiful houses. There was a fireplace in every room and usually a room or two extra, not because they were needed, but because they did not cost much and so we built them anyway. As our communities began to grow, it was found that houses began to cost more, and the more we built, the more they continued to cost. Then, in order to hold down the cost, we began to cheapen the quality, fireplaces were omitted, and less material was put into our construction. Then we reduced the size of the house by omitting unnecessary rooms, and again further reduced the size of the remaining rooms, but still the cost continued to go up. Then some of us began to give up the house and adopt the flat and apartment. But the same story repeated itself. The more we built, the more they cost. So again we reduced the number of rooms. Then we reduced the size of the rooms. Then we began all over again and reduced everything all around, that is, everything but the cost.

During the war, this frantic effort to hold down the cost resulted in some very bad industrial housing. Thousands of houses were built throughout this country which, while presenting a very pleasing exterior, were utterly impractical from a utilitarian viewpoint. Personally, I have seen such houses where it was only possible to get furniture to the second floor by taking it through the second story windows. I have seen many bedrooms where it was impossible to close the door to the hall, or open the door to the cupboard after the furniture was placed. I know of one development where, in a majority of houses, there was no place for the piano except over the hot-air register. Unfortunately for that particular development, the piano was, and in fact usually is, one of the work-

ingman's standard pieces of furniture and must be considered.

Three years ago, the United States Steel Corporation Companies began to devise a set of standard tests which are now applied to all house designs to insure against such results. These tests are the result of experience in designing and building thousands of industrial houses and are being developed gradually as we encounter weaknesses and objectionable features in the house design. The industrial house must meet three fundamental conditions:

(1) It must fit the average workman's furniture.

(2) It must be reasonably convenient and easy to care for.

(3) For economical reasons, it must be as small and compact as is possible without hurting the first two conditions.

A careful survey of all our existing houses enabled us to make up what we call a Minimum Furniture List, in which we have enumerated by size every item of furniture which the average workman owns. For instance, every bedroom in a Class No. 2 house must contain, in addition to a clothes press, room for one double bed. 4 feet 6 inches by 6 feet 6 inches; one dresser, 1 foot 10 inches by 3 feet 6 inches; one chest of drawers, 1 foot 10 inches by 3 feet; and two chairs, and we have a similar list for every room in the house. The first step in checking a plan is to draw in place all of the furniture to scale. The wall space must be such that this furniture can be placed without interference with doors, windows, hot air registers, and electric light switches.

The convenience of the house is checked entirely by observation. For instance, it must be possible to place all beds so that the housewife may dress them without pulling them away from the wall, and she must be able to get food from the ice box without going to the cellar.

Fig. 5—Group of detached houses, Homestead Park. These houses were built and sold to employes of the Carnegie Steel Co. under the provisions of the Home Owning Plan.

Fig. 6—A double duplex house for four families. Each family has its own entrance and front porch, its own inside stairway to own cellar, and its own heating plant.

Fig. 7—Hillside duplex house. The family in the lower part has its own front yard and porch fronting on a street.

Fig. 8—Hillside duplex house. View of same house shown in Fig. 7 from opposite side.

It is astonishing how many plans for industrial houses should be rejected by the application of these simple rules, but we now go much further. It is easy to get in the furniture and make the house convenient at the expense of wasting much room, and in order to check this, we have devised a set of rules for checking the efficiency of every type of industrial house. For instance, the efficiency test for a two-story, Class No. 2 house is as follows:

On the second floor only, we compute the floor area of all bedrooms, to which we add 42 square feet for the bathroom and six square feet for each bedroom clothes press. This total area must be at least 74 per cent of the total area of the entire second floor, or in other words, not more than 26 per cent shall be devoted to stairs, hallways, partitions, etc. If the percentage falls below 74 per cent, the plan is re-studied or else discarded.

After we had been using these tests for a certain length of time, we found that it was possible to meet the conditions we had laid down and still not have an economically designed house because it is possible, under these rules, to have the bedrooms larger than is necessary and thus raise the percentage of efficiency, and of course, the cost of the house. So at this point, we now bring in what we call a Cubage Test. The cubage of a house is the total number of cubic feet contained by the outside walls, the cellar floor, and the roof. It is obvious that in houses of identical materials and similar type of construction, the one satisfying the furniture requirements within the smallest cubage and yet having the highest efficiency percentage, combines best the desirable elements of utility, compactness, and low construction cost.

After applying these tests to many hundreds of plans, the Carnegie Land Company has finally selected seven model floor plans which enable it to build anything from four to seven rooms, either in the two-story or three-story house. Our cheapest house is built over a half cellar, contains no bathroom, and the dining room and kitchen, or

the dining room and living room, are combined as one room, while the better class of house contains separate rooms for these purposes, includes a bathroom, and is built over a full cellar. Each one of these seven plans can be built within the smallest cubage, yet each one

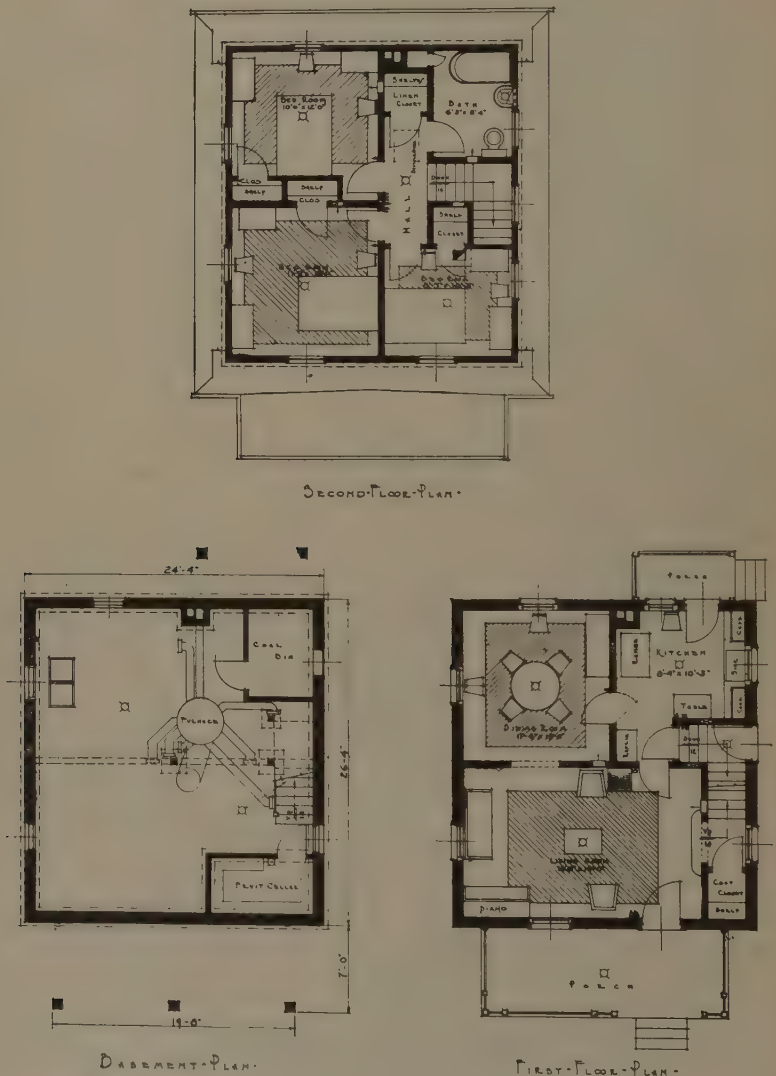


Fig. 9—Floor plan of six-room house, Carnegie Land Company.

meets all the necessary furniture requirements and shows the highest efficiency percentage.

It is not possible in a paper of this length to describe these tests in detail, but I believe if they were generally used, much bad industrial housing would be avoided.

We have also adopted many standards which tend to reduce the cost of the house. We have a standard ceiling height for each floor, standard size for windows and doors, standard wood trim for the inside of the house, standard hardware, and in fact we hope ultimately to

Fig. 10—A group of six-room houses, all built with the same floor plan as shown in Fig. 9.

have everything so standardized that only a very brief specification will be necessary.

One of the important benefits which has come out of this effort to reduce costs is that we have all discovered we do not really need as much house as formerly. In fact, we now welcome anything which tends to simplify housekeeping and the small house certainly accomplishes this.

The Housing Committee of the United States Steel Corporation, which is made up of representatives of its subsidiary companies, is making a careful study of all

these matters and has sub-committees at work on every phase of industrial housing.

There are still a great many problems in connection with industrial housing which are not satisfactorily solved. For instance, one of the gravest questions now confronting employers, who have housing developments, is the matter of obtaining adequate rentals. I have heard of very few developments in which the rents are producing anything like a fair return. In other words, such houses are being rented at rates which are far too low. This has two very bad effects: first, it has discouraged outside capital from building, because it cannot compete with the low rentals; second, it tends to influence the employe against owning his home.

In this connection, it is proper to mention the Home Owning Plan established by the Steel Corporation, whereby an employe may acquire his own home under easy and favorable terms, and which has been the means of many employes buying their homes, who without such a plan would still be renters.

Judge Gary: That completes the program for the morning. We are now to have luncheon. We will adjourn until two o'clock. Mr. Rogers will call the meeting to order at that time and preside during the afternoon. There are to be three discussions of this last paper. They will be taken up immediately after we resume at two o'clock.

(A recess was then taken until 2 p. m.)

Members assembled in the East Ball Room at two o'clock, Mr. William A. Rogers in the chair.

The Chairman (Mr. William A. Rogers): Gentlemen, Judge Gary, finding it impracticable to be here this afternoon, in the absence of the three vice-presidents, has asked me to preside.

I find myself a little in the position of Mr. Truesdale and the colored woman, because I feel that in this pres-

ence I need an introduction. Perhaps you have heard of the time when Truesdale of the Lackawanna and Underwood of the Erie were walking down Fifth Avenue, and passing a colored woman Truesdale took off his hat and bowed with great ceremony. Underwood said, "You are getting very democratic, what is the matter? Why did you bow to that colored woman?" "Oh," he said, "she is not colored; she is simply Phoebe Snow who came down on the Erie." (Laughter.) So she was properly introduced.

I want to say to you gentlemen who are here to read papers that you must not be discouraged by the small attendance. Your papers—if you do not know it, others do—reach a very large attendance, and I think all of you should feel amply repaid for the time you have given to the preparation of them and for all of the experience and qualifications that are back of the ability to deliver those papers.

I imagine the attendance today is smaller than usual due to the adoption of a plan by the board of directors of having all the papers printed and placed in the ante-room so that they could be read and taken home and be as available for others as for those present. That has undoubtedly militated somewhat against the attendance. But you are speaking to an unseen audience as well as those who are here present.

There were postponed from this morning's session the discussions by three gentlemen, all upon the industrial housing paper.

The first is a discussion by Mr. R. H. Stevens, Chief Engineer of the Midvale Steel & Ordnance Company, Philadelphia, Pa.

Discussion by R. H. Stevens

Chief Engineer, Midvale Steel & Ordnance Company, Philadelphia, Pa.

Mr. Wooldridge and his associates have undoubtedly given more thought to the housing situation as related to

the steel industry than any other group having to do with this most important and difficult problem and they are to be congratulated upon the success of their endeavors. The most satisfying congratulations, however, come from people who are living in the houses which Mr. Wooldridge has described in his paper and their satisfactory comments as to size and arrangement of rooms show con-

Fig. 1—Houses for common labor, Coatesville, Pa., Housing Development, Midvale Steel & Ordnance Company.

clusively that Mr. Wooldridge has indeed hit upon the proper methods in his studies of this problem.

The Midvale Steel & Ordnance Company was first confronted in a serious way with the necessity of providing homes for workmen in 1916 at the Coatesville Works, where we were compelled to provide houses for common labor and also for the higher classes of skilled labor required if we expected to keep the plants in full operation. The situation was so acute that it was impossible to pro-

cure houses for the men and they were not satisfied to be separated from their families and live in the camps which we first provided as a war-time emergency. Furthermore, camp life can only be viewed as a temporary expedient and cannot be considered conducive to the development of efficient workmen. We, therefore, entered into a house-building campaign and erected one hundred houses for

Fig. 2—Houses for skilled labor, Coatesville, Pa., Housing Development, Midvale Steel & Ordnance Company.

common labor which consisted mostly of immigrants from the middle European countries and seventy houses of the better class for skilled labor.

At that time houses were designed without so much regard to detail of arrangement or convenience of the house, but providing modern appliances such as bathrooms in the houses for the common labor and heating furnaces in the houses for the more skilled labor. One of the difficulties in providing a bathroom for the average

laborer is the fact that he will not keep the room sufficiently heated if it is added as a separate unit and is not connected to a room which is usually kept warm. This condition led us to place the bath tub in a room which opened off the kitchen where most of the family live amongst this class of people. The door leading from the kitchen to the bathroom was provided with a slatted portion so as to allow a circulation of the air for heating this room. I might add that in this development for common labor, while we provided bathrooms for the benefit of the workmen they were not always used for the purpose intended. Some were used for the storage of coal, others for the storage of beer (this, of course, being before the eighteenth amendment went into effect). No doubt now the bathrooms are being used for their legitimate purpose. We, however, were not discouraged because of this fact, as we believe the children in these homes will eventually bring their parents to realize the proper use of the bathroom, and they will insist upon the use of it themselves, which all tends to make future desirable citizens. By reason of our housing development the results in the works were eminently satisfactory and the experience gained was of very great benefit in our later developments.

In the latter part of the year 1919 we were faced with a similar situation at our Johnstown Works, due to the enlargement of these works, and we found it necessary to build houses to induce workmen to accept the positions which we had to offer. Based on the information developed in a canvass of the workmen as to their requirements, we decided to build thirty-four five-room houses and sixty-six six-room houses of the hundred contemplated. In locating our Johnstown development we endeavored to get the houses on an established street-car line and within a single-fare distance of the works and also of the center of the city.

Before building the Johnstown houses we decided to investigate the housing facilities then being provided by

the Carnegie Steel Company and through the courtesy of Mr. Wooldridge, were permitted to inspect the several housing developments that this company had undertaken. We very readily saw the advantages of planning the houses to suit furniture and immediately adopted their plan and had a number of designs prepared and submitted along the lines of the Carnegie Steel Company houses with numerous changes and improvements as

Fig. 3—Houses for skilled labor, Johnstown, Pa., Housing Development, Midvale Steel & Ordnance Company.

suggested by Mr. Wooldridge and also as disclosed by our inspection. The original plans were prepared without special regard to the exterior appearance of the houses, the main endeavor being to make a highly efficient interior. We encountered some little difficulty in holding the architect to the location of windows, doors, etc., but insisted that he maintain the clearances provided and also that he should not make any changes in the interior that would lessen the adaptability of the furni-

ture to the rooms. They, however, were able to work out very satisfactory exterior designs.

In both our Coatesville and Johnstown developments we were confronted with a hillside problem which made it very difficult to adopt any elaborate scheme of grouping of buildings, such as has been developed more recently in other industrial communities where the topography was more favorable. In our Johnstown development, where

Fig. 4—Houses for skilled labor, Johnstown, Pa., Housing Development, Midvale Steel & Ordnance Company.

all flat ground contiguous to works has been preempted, it was necessary to use the hillsides available for this development, causing extremely high street costs, as we could not place more than one row of houses between each street, and even then the terraces are extremely high. In our Coatesville development we are experimenting on some of the terrace problems by the use of large chunks of open hearth slag set in the terrace irregularly and planting flowers or creeping vines between, which will probably develop a solution for the high terraces. This

will not only be a saving in general upkeep, due to keeping the slopes in grass, but beautifies the landscape to a very great extent.

After investigating the different types and costs of construction of houses at that time, we determined for our Johnstown houses on the so-called "Van Guilder" system, which consists of two independent thin concrete

Fig. 5—Houses for skilled labor, Johnstown, Pa., Housing Development, Midvale Steel & Ordnance Company.

walls separated throughout the entire height of the building with an air space approximately two inches wide, each portion of the wall being connected by means of galvanized wire and a reinforcing wire running longitudinally around each section of the wall, both the connecting wires and reinforcing wires located every nine inches of height. With this type of house it is very easy to keep warm with a low fuel expenditure and in some instances we have been advised that it was difficult to keep

the house cool enough. This no doubt was because of a very active fireman. On some of the tests which we made on this type of house, not heated, we found that while there was a drop of 25 degrees of temperature outside there was only a drop of two degrees inside. This is not only an advantage in the winter in keeping the house warm but is also an advantage in the summer in keeping the house cool. The outside walls were stuccoed direct on the concrete and due to the air space between the outer and inner walls we were able to plaster on the inner wall without furring or lathing so that there was a material saving in this respect. One of the important features was to design a house that would require but little repairs and upkeep and in this type we believe upkeep will be at the minimum.

It has not been necessary in any of our developments to establish recreation centers as they are located close to the city where there are parks and playgrounds already established by the city and ourselves as well as by other organizations.

One of the serious items confronting both industries and individuals during the past several years and which still maintains is the high cost to build due to the original material cost, assemblage expense under existing freight rates, and high labor costs in the building trades, so that a house which we feel is proper and suitable for our workmen costs too much to build and the company has to charge off too much of this cost to put the house within the range of the average workman's income, this applies both to houses to be sold and those for rent. We have, therefore, been giving considerable thought to a simplification of houses so as to maintain the principal features but cut down the cost. This will no doubt tend to plainness of the exterior and duplication in appearance and even possibly cause a return to the old undesirable rows.

The Chairman (Mr. William A. Rogers): The next discussion of this paper is by Mr. Paul C. Kuegle, Mana-

ger, The Buckeye Land Company, a subsidiary of The Youngstown Sheet & Tube Company.

Discussion by Paul C. Kuegle

Manager, The Buckeye Land Company, subsidiary of The Youngstown Sheet & Tube Company

The experiences of The Youngstown Sheet & Tube Company, in the industrial housing field, agree so closely with those stated in the preceding paper that discussion, at least in a critical sense, is scarcely possible. Owing to this similarity of experience, this paper must confirm practically all of the statements of the preceding one, and will deal further with certain phases of the industrial housing situation.

In Youngstown, as in other industrial centers, the World War brought to an acute stage a housing shortage, which, for a variety of reasons, had been accumulating for some years; and in 1916 it was realized that the mills of The Youngstown Sheet & Tube Company could not be further speeded up, or further expanded, unless some steps were taken to provide living accommodations for additional men. As was everywhere the case, private building was not keeping pace with the rapidly increasing demand for more workers and more homes.

The Youngstown Sheet & Tube Company, therefore, felt it necessary to take up the housing problem. It organized a subsidiary company, called The Buckeye Land Company, and purchased approximately six hundred acres of land in various localities within walking distances of the plants. This all being unplatted land, outside of municipalities, it was necessary to plan the streets, and develop most of the public utilities. Several suitable portions of this land were set aside for park and recreational purposes. These are so located as to be easily available for all residents of the various communities, and, as is usual, time will very probably prove the wisdom of this action. One of the largest parks,

named after Mr. James A. Campbell, President of The Youngstown Sheet & Tube Company and The Buckeye Land Company, has been equipped with recreational devices such as a ball park, dancing pavilion, race course, etc.

Realizing the importance of proper planning, and being desirous of working to high standards, it employed well known experts for this purpose. Mr. John Nolen, of Cambridge, Mass., a well known city planner and land-

Fig. 1—Group houses for colored employees, Blackburn Plat, Youngstown Sheet & Tube Company.

scape architect, had charge of some of this work, and Mr. Franz Herding, a Swiss city planner and architect, of St. Louis, had charge of another portion. The utilities were designed by Mr. Morris Knowles, sanitary engineer of Pittsburgh, who was later appointed Chief Engineer of the Division of Housing, United States Shipping Board.

The company early recognized that employees of widely varying housing requirements should be provided for, and also recognized the necessity for some degree

of separation for their home communities. It also adopted the policy that only substantial, comfortable homes should be built, having in mind the great importance of pleasant healthful home surroundings. On its various properties it has so far located and built homes to as nearly as possible fit the earning capacities of different grades of employees, namely: 146 apartments in concrete buildings for rent to white foreign employees;

Fig. 2—An architectural detail in the colored colony, Blackburn Plat, Youngstown Sheet & Tube Company.

135 similar apartments for rent to colored employees; 110 apartments in two-family brick houses for rent to white employees; 50 single-family frame houses for sale to white employees, and 111 single-family frame houses for sale to the higher paid white employees.

Except for the fifty single-family frame houses, where sewers are not yet available, all these houses are completely equipped with bathrooms and modern conveniences. The houses of the excepted group are planned for

the later installation of bathrooms, and now have water service in the basements and kitchens. This group we had hoped would be purchased by the better grade of foreign employees.

The selling terms of the groups designed for sale are liberal. The principal features of the contracts are a nominal payment down, future monthly payments at the rate of 1 per cent. of the balance, 5 per cent. interest on unpaid balances, and monthly adjustments of principal. Life insurance is provided whereby the balance on the account will become paid up, and the deed delivered, in case of the death or total disability of the purchaser during the life of the contract. This life insurance feature has already proved of value in three cases; two being settled on a basis of total disability, and one by death. The company does not retain any options or restrictions whatever, either before or after the delivery of the deed.

In addition to the houses already mentioned, all of which are near the steel works at Youngstown, Ohio, another subsidiary, The Buckeye Coal Company, has built a complete town at the coal mines in Green County, Pennsylvania. This town was planned by Mr. Franz Herding, the same architect who planned the foreign and negro colonies before mentioned. The houses are classed as follows:

39 6-room single-family houses	39 families
80 5-room single-family houses	80 families
11 4-room single-family houses	11 families
60 Double 5-room houses	120 families
1 4-family house (2-5 rooms) (2-6 rooms)	4 families
Altogether providing homes for	254 families

In addition to these houses at the mines it has also built a modern schoolhouse, general store building, public hall and theater. Being entirely isolated from all other communities it was here necessary to provide all of the ordinary public utilities. None of the houses in this town are for sale, but are rented to employees of the coal

company at nominal rents. They are all equipped with water and light, and have sanitary sewers and disposal plants complying with the requirements of the State of Pennsylvania. Regardless of the moderateness of the rents, there is a constantly increasing demand for better houses and more conveniences, and the demands on capital are becoming increasingly heavy.

As no extensive second building program has as yet

Fig. 3—Precast concrete slab houses, Blackburn Plat, Youngstown Sheet & Tube Company. Note their adaptability to sloping ground.

been required for any of these classes of houses, either at the mines or at Youngstown, we have not crystallized our ideas into fixed standards, but are still accumulating data on the desirability, utility, and economy of various types. We find the present readjustment period is bringing about many changes in employees' ideas of homes, and further stabilization along this line is to be expected.

The details of these various plats are many and varied, and beyond the scope of this paper. We will therefore pass on to some of the outstanding results and

lessons of our experiences, believing these to be of greatest importance to the members of this Institute.

Referring, first, to the houses built for sale to the more skilled foreigners: Our experiences in this connection are rather disappointing. It is our present general conclusion that comparatively few foreigners appreciate the value of sanitary surroundings, comfortable adequate houses, and an opportunity to really improve their manner of living. But we may be wrong in this opinion, as there are several factors which must be considered, such as the steel strike of 1919, which occurred just when this plat was first being sold, and the industrial depression of the past eighteen months. The return of more normal times, and another effort will finally determine the advisability of this kind of housing.

Second: It is a mistake on the part of some social workers to imagine that people of various European races will not live reasonably close together. In our white foreign colony we have never had race trouble of any kind, although we have a general assortment of races, Slavish and Hungarian predominating.

Third: We believe it is wise to build, if possible, within the limits of municipalities, so that the usual utilities such as water, sewage, light, garbage collection, police and fire protection may be handled by existing organizations. This prevents friction between the company and its employees over the correctness of meters, and criticism regarding the efficiency of the services they expect to secure in ordinary municipal affairs.

Fourth: We believe it to be unwise to introduce revolutionary changes into the ordinary domestic customs of employees. In building single-family houses especially, it seems better to produce the ordinary substantial type of American home rather than to carry standardization to too great an extent. Our experience teaches us that no matter what minor outside changes are made in design, in the way of arrangement of porches, color, etc., too many houses of a single style of architecture will be

monotonous, with the result that they will, to some people, always be "company houses."

Fifth: It is questionable if the building of single-family houses for sale to high-grade Americans comes within the proper scope of industrial housing. In this connection must be considered the usual remoteness of suitable locations, the great investment per worker required, the liberal terms expected, and the general independence of American employees, who, if they are thrifty

Fig. 4—Five- and six-room double houses for rent to white employees, Overlook Plat, Youngstown Sheet & Tube Company.

enough to want to own their own homes, generally want to handle the proposition themselves. Industrial housing seems to be more necessary for renters than for purchasers.

Sixth: And perhaps of greatest interest to this gathering is the result of housing during acute labor shortage or labor trouble. Regarding the former, I believe there is no question but that housing helps get and keep labor, as the way homes are snapped up during such times plainly indicates. Our experiences during labor troubles

are as follows: the general opinion that the steel strike of 1919 was largely fostered and propagated among foreign employees was easily confirmed. At the commencement of that strike, almost without exception our foreign renting tenants stayed away from work, but after a few days, on finding that their homes and families were being protected, they began to filter back to the mill, and before long the best of them had returned. Some of course never did, and while we were disappointed in the

Fig. 5—Homes for sale to the higher paid employees, Loveland Farms Plat, Youngstown Sheet & Tube Company

first general completeness of their remaining away, we feel that the general effect was encouraging.

The workers in the negro colony were loyal to the company almost to a man.

The sentiment among the foreign purchasers of homes was about equally divided, and disappointing to the company in that so many men were not loyal.

Among the 111 American purchasers only one man proved disloyal, and during the trouble the loyal men did not hesitate to take up almost any kind of burdens,

knowing that their homes were being patrolled and their families safe.

Mr. Wooldridge states the facts correctly in saying that the diversion of capital from housing to other forms of investment, the automobile, etc., has contributed to the shortage of housing, and that the inadequate financial return from houses erected by corporations still further tends to discourage the investment of private capital in homes. This phase of the problem is its most unsatisfactory one, and I believe the only promising solution for industries to be in the development of the multi-family house for renters.

There does not seem to be any rapid progress in the evolution of house building, and none of the departures from the usual frame or brick house, such as moulded houses, plaster houses, or portable section houses, are widely accepted as practicable. We believe our pre-cast concrete slab houses for renters are well adapted for their particular purpose, but there are a number of limitations to the adoption of the plan, such as the great plant and equipment cost except for a large number of houses, and the monotony of the architecture unless relieved by rugged ground, curving streets, or many trees.

Finally it is our opinion that the control of housing by corporations is outside of their proper sphere and should not be engaged in where private capital is supplying an adequate number of homes for labor. These are some of the phases of the housing problem which have been put upon industries, and while they will differ with localities, many of their main features will undoubtedly be found common to all.

The Chairman (Mr. William A. Rogers): The third speaker in conjunction with this industrial paper of Mr. Wooldridge is Mr. Walter J. Riley, Vice-President, Indiana Harbor Homes Company, a subsidiary of the Inland Steel Company, Indiana Harbor, Indiana.

Discussion by Walter J. Riley

Vice President, Indiana Harbor Homes Company, a subsidiary of the Inland Steel Company, Indiana Harbor, Ind.

Housing projects are undertaken by industries to locate employees conveniently to the plants, thus stabilizing labor conditions. Tenants as a group are not the steadiest workmen. Industrial corporations as landlords contend with a difficult and thankless task and do not have heroic rôles in the eyes of either their employees or the public. Therefore, the first aim of housing projects should be to make home owners.

The most effective method of industrial housing is the one whereby the employee is financed to build a home from plans arranged according to the ideas of himself and wife. Where this is not possible, the unit of the housing project should be planned so that it appeals to the woman of the house. Unless she is satisfied, all other efforts fall below the mark.

Industrial housing may be divided into two broad classes.

Two Broad Classes of Housing

In the first group are housing for unmarried employees and houses for laborers and their families. Necessarily these houses are rented.

In the second group, with which my discussion has to do, are:

(a) Industrial housing in a stabilized community, provided for the better class of employees. Dwellings are built with the intention of renting, and, if possible, of selling them to the employees.

(b) Where the industrial corporation furthers housing by supplying money for first or second mortgages, or both, either through a bank or other agency.

The corporation that encourages home building by

financing the employee gets the maximum of results at minimum cost and effort.

Build Houses That Can Be Sold

Mr. Wooldridge has given us the benefit of telling of the scientific tests that the steel corporation has worked out with respect to its several housing enterprises. But all tests are subordinate to this fundamental rule: Build houses that can be sold. If you do that, you meet the expert specifications of Mr. Wooldridge, conform to the requirements of the housewife, and accomplish the first aim of industrial housing—make homeowners and get steady employees.

Some Things To Be Avoided

Avoid the duplex type of house and the row. They are in the class of property not easily sold.

Have lots of satisfactory size.

A subdivision with lots so small that the backyard cannot accommodate the Monday morning clothesline or the family garage is objectionable. Such lots hinder the sale of the property. In the long run, lots of average size are the most economical.

It is not enough to be up-to-date in giving the workman's home plenty of sunlight and the advantage of a community playground. Also give his family a yard that can be useful. A yard of no more than average size, with its possibilities for flowers and home gardening, encourages community development, promotes health, increases contentment, and pays good returns to the employer.

In this connection, community development and family pride can also be aroused by furthering the town beautiful idea. Offer to pay part of the sprinkling bill where the occupant of the dwelling takes an interest in the appearance of the property. Or further stimulate this interest by bringing about competition through offering prizes for the best-kept lawns, flower beds and

gardens. Handling the situation this way is an incentive to the occupant of the dwelling, whether purchaser or tenant, to do the thing which the industry might otherwise feel itself obliged to perform.

Housing is more satisfactory to all concerned, if attention is given to the two rooms in which the woman of the house works—the kitchen and the basement. There are important possibilities in the basement. It should be well drained, of sufficient height, sun lighted, and have convenient laundry arrangements.

In these days we have to take into consideration the growing use of the automobile. The workman's family is no exception to this rule.

If the housing project is such that yards in rear of houses are limited in size, there should be a centrally-located community garage. Whether the community garage is operated by the industry or privately maintained, the storage charge should be controlled so that it does not become prohibitory.

Do Not Overlook Marketing Facilities

A mistake in some housing projects is the failure to have handy marketing facilities. Sometimes stores are either barred altogether or restricted to inconvenient points. It is better to have a nearby marketing center.

The housewife is the purchasing agent of the home, and coupled with her natural buying abilities is an inherent desire to go shopping. This ought to be recognized.

Store buildings to house a market, grocery, drugstore and soda fountain, and perhaps a restaurant, not forgetting the indispensable barbershop, are essentials that should be given consideration if the immediate neighborhood offers no trading facilities.

Avoid The Monotony of Company Houses

As time goes on and industrial housing becomes more of a science, the stamp of monotony that has marked it

gradually diminishes. We easily recall how repellant was the stereotyped form of company housing in the old days. And even now it requires care and study to minimize the tell-tale marks of group housing, for economy dictates that the number of types of houses shall be limited. But it is possible to plan so that the spirit of sameness is almost effaced. This can be done by making changes in the elevations, ingeniously interspersing the several types, and varying paint colors. Effective landscape architecture, sidewalk electroliers, and even winding lanes instead of the customary street plan, add charm to group housing and in consequence enhance possibilities of home sales.

The Bane of Paternalism

The charge of paternalism attends industrial housing projects in more or less degree. To be sure, there will always be people who are unappreciative, and who will question the finest of motives. As long as the industrial corporation must play the part of landlord, an inevitable result is the accusation of paternalism, which is heaped on it in a most unjust measure. So whatever is undertaken should be carried out with the minimum amount of paternalism.

We should be frank about it, and admit that paternalism cannot be entirely avoided, however much we recognize it as an undesirable condition. This plague is a greater source of grief and vexation to the employer than it is a cause of resentment on the part of the workman. To eradicate it as far as possible requires carefulness in planning and vigilance in management. And to minimize paternalism, we again attend to the fundamental principle of industrial housing. Build such types of houses and provide such lots that employees may and will buy them.

Second in importance in avoiding paternalism is that the industrial corporation (except where it has no other

alternative) should refrain from operating the stores and business places. This, however, need not prevent the company from inserting in its leases restrictions intended to keep tenants in its commercial buildings from overcharging.

In conclusion, let me again stress the object of an industrial housing project: Increase the number of home owners, stabilize plant labor conditions, and thereby reduce production costs.

THE CHAIRMAN (Mr. William A. Rogers): Are there any gentlemen who would like to discuss Mr. Wooldridge's paper under the limitation of the five-minute rule?

If not, we will take up the regular order for the afternoon session by calling upon Mr. Wilfred Sykes, assistant to operating Vice-President, The Steel & Tube Company of America, Chicago, Ill., to deliver his paper upon "The General Effect of Electrification of Steel Mills Upon Their Operation."

THE GENERAL EFFECT OF ELECTRIFICATION ON THE OPERATION OF STEEL MILLS

WILFRED SYKES

Assistant to Operating Vice-President, The Steel & Tube Company of America, Chicago, Ill.

A number of papers on electrical subjects have been read before this Institute, practically all of which have dealt with technical details of some particular piece of apparatus or some installation. These papers undoubtedly have been of interest to engineers, but of our membership, the greater part is concerned only with the general effects of engineering and I think discussions of electrical problems have received limited attention. This is unfortunate, as electricity is becoming every year a greater factor in our operations and the executives and operators are being called upon more and more to make decisions on electrical matters. The history of the electric drive in steel mills is comparatively recent and an understanding of some of the essentials of successful electrification is desirable on the part of those concerned, who make no pretension of being electrical engineers. The apparent lack of interest in electrical subjects by such executives and operators is probably due mainly to two factors. In the first place, when dealing with electricity, the man who has not been trained in the art naturally feels that it is somewhat mysterious. We can all understand how steam pressure, applied behind a piston, can be used to develop power and we can visualize the whole process of the generation of power from the evaporation of water in the boiler, flow of steam through a pipe and the conversion of the energy in the steam to mechanical work, as we are dealing with a medium with which everyone is familiar. When we

come to electricity it seems to be intangible and unless one has a clear conception of its fundamentals, electrical phenomena are mystifying. The second factor which troubles the non-electrical man is the vocabulary of this branch of engineering. When we talk of volts, amperes and ohms, they do not convey a physical meaning in the same way as do such terms as pressure per square inch, pounds per hour flow, or pressure drop in a steam line; and when we talk of such things as induction, reactance and frequency, we seem to be dealing with abstract conceptions which, to anyone not trained in the art, are difficult, if not impossible, of comprehension. Electrical engineers frequently do not appreciate these facts, and consequently there is often a lack of understanding between the men who are responsible for the building or rehabilitation of our steel plants, or between those responsible for their operation, and the engineer. The subject is frequently rendered more confusing by the heated arguments which take place between the manufacturer's representatives and our engineers as to the way in which the problem should be solved, and if the executive or operator is not familiar with the subject, it is frequently very difficult to arrive at the correct decision. When the program committee suggested the title of "The General Effect of Electrification Upon the Operation of Steel Mills," it seemed to me that a plain statement of the general situation would interest a large proportion of the membership and possibly be of some guidance to them when making decisions upon electrical matters.

It is only about thirty years ago that electricity was first introduced into steel plants for motive power purposes, and for many years it was a very small factor and was used only in those places where mechanical drives were difficult, such as traveling tables, cranes, etc. Later, due to the experience gained with such applications, it was used for other auxiliary purposes around the mills, again mainly on account

of convenience, and while good results were obtained, development undoubtedly lagged due to the lack of suitable apparatus. However, when enough mills were interested in the subject to make it profitable for manufacturers to build special equipment for the severe operating conditions, a rapid improvement took place, which added greatly to the reliability of these auxiliary drives, and the present generation of operating men takes the electrically driven auxiliary as a matter of course. While he may not be interested in its details, it has become such a familiar tool that it is no longer questioned. When we come to discuss the main drives, there is perhaps not such a clear understanding as to the reasons for the replacement of the old and well tried steam engine. In the case of the auxiliaries, questions of convenience, reliability, and easy maintenance are important enough to justify the use of motors, even if the operating costs were considerably more than they actually are; but in the case of the main drive, the steam engine has apparently operated as well as desired, and due to a long period of development, it has reached a stage where it gives reliable operation, when properly designed for mill service. Therefore, perhaps it would be well at the outset to get a clear conception of why we electrify mills as, frequently in discussions, details so confuse the issue that the fundamental reasons are lost sight of.

The reason for electrification is fundamentally due to certain inherent characteristics of the generation, distribution and utilization of electricity. Electrical generating stations use prime movers of the most economical type known today and of such size as to give the best operating results, independently of the size or characteristics required for any particular mill or other consumer of power. The combination of generating units in service depends only upon the combined load of all the mills that may be running and the available capacity can be varied

rapidly to supply the demand for a greater or a lesser output and still maintain a high operating efficiency.

Frequently we have a choice as prime movers of either internal combustion engines, using blast furnace gas, or of steam turbines. The former, while having a better fuel economy, are limited by constructional difficulties to sizes of not larger than 3,000 to 4,000 H. P., so that a large plant requires a great many individual generating units. The steam turbine can be built in any size that is required for even our largest plants and the limit of output of a single unit has not yet been reached. The first cost of a gas engine driven station is at least twice as much as a modern steam station and this frequently is sufficient to offset the better economy. Continual improvements are being made in the design of steam stations which tend to reduce this difference in economy, and the situation today is that the difference in the number of heat units required in the fuel under average operating conditions probably does not exceed about 15 per cent. This is the overall efficiency from the fuel to the switchboard. The result of this freedom of choice of prime movers and the facility with which different combinations of machines can be run, to take care of the varying operating conditions, makes possible a very much better utilization of the energy in the fuel than is possible with any type of prime mover driving the mill direct.

Another advantage of centralizing the power equipment is that, due to the diversity of the mill loads, the average that has to be carried by the central station is very much less than the summation of the loads that occur on the individual consuming units, and the fluctuations of load are less, so that the prime movers can be run at more nearly their most economical output.

The conversion of the output of the prime mover into electricity is accomplished with a loss that seldom exceeds 5 per cent. with modern equipment.

Perhaps the greatest economy of electric drive is due to the small loss with which this form of power can be

distributed and the fact that the loss varies with the load so that the lines can be kept charged ready to supply power as demanded and loss only occurs when power is actually being used. Even at full load the loss in the lines seldom exceeds one or two per cent. If we contrast this with steam distribution, the saving is very obvious. Anyone interested in making up steam costs in a mill knows that, even after making what appears to be very liberal allowances for the consumption of the different engines based on the output of the mill, there remains a very large amount of steam not accounted for; and I think it would not be an overstatement to say that we can seldom account for more than about 50 per cent. of the steam generated, consequently the difference must be pro-rated over the different mills. It is therefore very misleading to talk of any engine consuming so many pounds of steam per horse-power or per ton of steel rolled, unless we take into consideration this factor since what we are really interested in is the amount of fuel used as gas or coal to roll a ton of steel. This is a condition with which every mill engineer is familiar and even the best laid out and operated plants do not appear to be able to avoid it. With modern engine drives, quite good efficiencies are obtained under test conditions although, of course, not as good as can be gotten in a properly laid out central power station.

To convert the electrical energy to mechanical work we must use motors. The efficiency of a continuously running motor under the varying conditions of load will usually average well over 90 per cent. In the case of a reversing mill, which involves first the conversion of electricity from one form to another and then into mechanical work as well as providing for equalization of the peak loads, the overall efficiency from the switchboard to the mill coupling will run over 75 per cent.

In any discussion of economy we must be careful to distinguish between theoretical figures and actual operating results, as what we are interested in is the overall efficiency from the energy in our gas or coal to the mill

coupling during a month's or a year's operation and the only teacher of any value is experience. The best measure is our power cost per ton of material shipped. Complete electrically driven mills show decided advantages when this measuring stick is applied to the question.

As a matter of interest, I am giving a few figures of two reversing mills in our plant, one being the reversing blooming mill and the other the reversing universal plate mill. The former rolls ingots (20″x22″, weighing 7,300 lbs.) to blooms averaging about 6″x8″ for the billet mill, and ingots (16″x38″, weighing 10,500 lbs.) to slabs for the plate mill. The plate mill rolls the slabs from the bloomer to skelp for the pipe mills, a typical range of which is given later in this paper.

POWER CONSUMPTION OF REVERSING MILLS, STEEL & TUBE COMPANY OF AMERICA FOR 1920

Kind of Mill	Gross Tons of Ingots or Slabs Rolled	K. W. Hours per Ton, Main Drive Only	Power Cost per Ton, Main Drive Only
Blooming mill.....	444,510	16.2	17.8 cents
Plate mill.........	191,524	31.9	35.1 cents

Average coal cost per ton at boiler house during year = $5.07.
Gas charged for at coal price on basis of equivalent evaporation

Closely connected with the subject of economy is the question of mill layout. The facility with which electricity can be distributed relieves us of the necessity of considering power distribution and mills can be arranged in the best possible manner for operation without having to face any disabilities on the score of power economy.

To sum up, with a central station we manufacture our power wholesale and through a very cheap distributing system we deliver it to the consumer as required. If the mill does not require power, it does not have any losses to take care of. It is very much the same situation as exists in the commercial field. If we had poor distributing facilities for our commodities, it would be necessary to have a great many plants scattered over the country to take care of local demands, some of which would be busy and some idle with a consequent low average efficiency.

As it is, we build a few plants in favorably situated localities and ship to the consuming points as required. We pay freight only as we ship. The demand of one locality frequently balances a lack of demand from another, so that our plant can be run at a good average load and efficiency.

The statement is sometimes made that electric drive is more expensive than a steam drive. I doubt very much

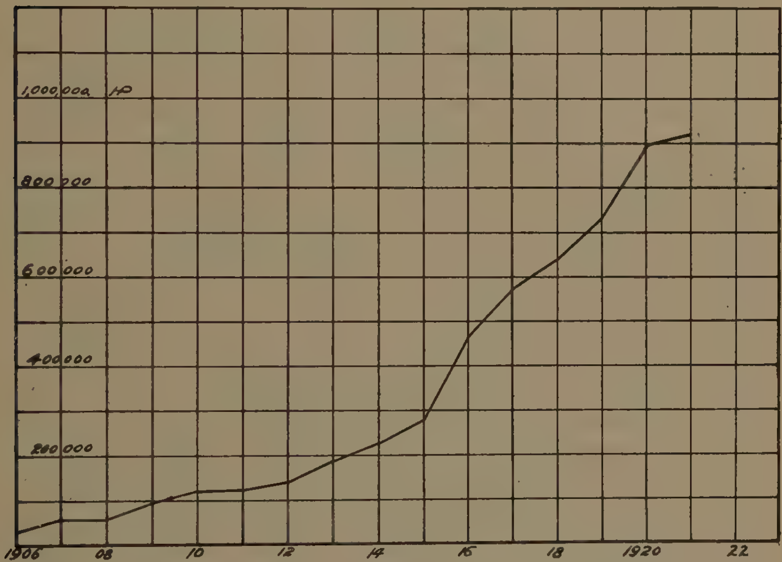


Fig. 1—Total horse-power of motors of 300 H. P. and above used for driving main rolls in the United States.

if this is really so when a true comparison is made of all the factors that must be taken into consideration, such as boiler plants, steam distribution, water distribution, sewers and many other items that affect the total cost of the plant. Too frequently, in discussing this question, comparisons neglect important items which, while difficult to estimate, must be considered.

After all, the proof of the pudding is in the eating. If electrification did not offer advantages, it is hard to understand why it has been so extensively adopted in recent

years. In Fig. 1 is a curve that shows the growth of the horse-power of motors used for driving main rolls in units of 300 H. P. and above and it will be seen that the total is approaching a million horse-power. The curve indicates the increase in popularity of this form of drive as experience is gained. It can be safely stated that practically all modern plants are electrically driven. In fact electricity is almost exclusively used where the plants have the benefit of good and mature engineering advice.

The rapid extension of steel-making and finishing capacity in recent years would indicate that in the immediate future the problem will be not so much extensions, as a rehabilitation of the older plants to enable them to operate with such efficiency as to be competitive, and this will require careful consideration of electrification as a means to this end.

Before leaving this phase of the subject, it is perhaps well to point out that the necessity of generating electricity for auxiliary purposes, regarding which no one questions the advantages, requires stations of substantial output. The following table illustrates this point and shows the power used for main drives and for auxiliary purposes at the Mark Plant during the year 1920. It will be seen that if the mills were driven by engines, a large proportion of the total power would have had to be electrical in any case.

Mill	Main Drive Only, K. W. Hours	Auxiliary Purposes, K. W. Hours
Blooming mill	7,061,000	5,040,000
Plate mill	6,111,000	2,967,000
Billet mill	2,920,000	1,890,000
Skelp mill	7,700,000	
	23,792,000	9,897,000

Total power generated	53,428,000 K. W. Hours	
Consumed, main drives	23,792,000 K. W. Hours	44½%
Consumed, mill auxiliaries	9,897,000 K. W. Hours	18½%
Consumed, other parts of Steel and Coke Plant	19,739,000 K. W. Hours	37%

Production.

Leaving the general characteristics of electrification I will endeavor to answer some of the more important questions that interest the executive and operator. The first question that is asked regarding any method of driving our mills is whether it will enable us to get the desired output? This is not only a question of the amount of power available but of the characteristics of the driving unit and the subject must be considered in relation to the different types of mills.

Continuously Running Mills

In the case of a mill running continuously in one direction, there are practically only two points to be considered. The first is the power, the second is the speed characteristic. As far as power is concerned, any output required by our mills presents no unsolved problem to the motor designer. Very much larger motors than any individual mill is likely to need have already been built. I believe the highest rating of any machine driving a continuously running mill is that of the motor driving the 160″ plate mill at Gary, Indiana. This motor is nominally rated at 7,000 H. P., but to meet the particular specifications, it actually has a continuous capacity of about 9,000 H. P. In operation this machine very frequently carries peak loads up to about 18,000 to 20,000 H. P. The largest electric motor that has been built to date has a continuous rating of 22,500 H. P. or more than twice the capacity of the 160″ plate mill motor and there is no particular reason why larger machines could not be constructed if there was any demand for them. As far as power is concerned, it is only a question of determining how large the motor should be. When we first started to electrify mills, very little data was available that would enable us to determine the proper characteristics. When it was attempted to translate indicator cards from existing engines into terms of motor output it was frequently

lost sight of that the speed characteristics of engines and motors are very different and the indicated horse-power readings could be very deceptive, especially if the inter-relation of engine output, speed, and fly-wheel action were not carefully analyzed. Consequently, in the early days some mistakes were made, although on the whole it is surprising how few. Information that could be gathered from mills as to production was frequently fragmentary and it was early evident that if satisfactory results were to be obtained the electrical engineer would have to study mill operation and conduct such tests as would enable him to analyze the requirements. A great deal of work was necessary to enable this to be done, but real progress was not made until the manufacturer could tell the mill man that he could supply an equipment that would roll so many tons of finished material under defined conditions. This was something that was perfectly definite and subject to ready tests. It involved not only motor design but also cooperation between the electrical manufacturer and the purchaser on the subject of the type of connections between the motor and the mill, and the size of the fly-wheel and its location. Today, there are so many installations in operation and so much accumulated experience that the problem is comparatively simple and it is mainly a question of deciding the output required, keeping in view the possibilities of electric drive and of improvements of mills and auxiliaries which enable material to be handled more expeditiously. In this respect it is fortunate that the electric motor has a practically constant high efficiency over a very large range of load, varying usually not more than ½ to 1 per cent. from one-half to full load, and also that the power station is so flexible that, if a machine is too large for the immediate requirements, the net effect on efficiency is practically negligible. It frequently happens that it is difficult to definitely specify operating conditions or that conditions will change after the mill has been installed and it has been my experience that it is wise to be

liberal in choosing the size of motor, as the only disadvantage in doing so is a slight extra outlay which, in relation to the total mill cost, is trifling.

Regarding the speed characteristics, the ordinary motor tends to run at a practically constant speed independently of the load. Where a fly-wheel is used, the object is to assist the motor in carrying short time peak loads. For instance, in the case of a plate mill, the early passes may require four to five times the power of the motor for a fraction of a second. It can be arranged very readily that the motor will take a certain proportion and the fly-wheel supply the remainder. When the passes become longer, the peaks are reduced and the motor then carries a greater proportion of the load. By the proper inter-action of the motor and the fly-wheel, an economical balance is arrived at. The speed characteristics of the motor are usually varied by means of the control equipment and they can be readily adjusted to suit individual operating conditions. In the case of mills where the passes are long, the fly-wheels are of less value and it is frequently desirable that the speed remain practically constant, which is the inherent characteristic of the motor. We therefore have the possibility of either maintaining the speed constant within two or three per cent or of regulating it to give the best operating results, depending on the load condition. Sometimes the characteristic of constant speed enables us to obtain greater output as compared with an engine which usually does not hold its speed so well under heavy load; and in some cases that have come to my attention, it has been stated that the mills have an output of 5 to 10 per cent greater when electrically driven. In this connection it should not be lost sight of that the ordinary mill motor can carry double load for short periods without any particular sacrifice of efficiency or any great change of speed. Of course we want to run the mill as fast as the metal can be properly rolled and frequently the speed at which the metal can be entered into the rolls is the controlling feature,

so it is obvious that the closer we can hold the average operating speed to this maximum, the greater will be the output.

Reversing Mills

There has been more discussion regarding the motor driven reversing mill in comparison with the steam engine drive than of any other type and this is quite natural, as the motor is an invader in the field for which the engine seems to be particularly well adapted. Quickness of manœuvering and ease of speed control is of the utmost importance for a successful drive. This will be appreciated when it is realized what a comparatively small percentage of the time the metal is in the rolls. An analysis made of a number of steam and motor driven mills shows that in the case of a blooming mill operating rapidly, the metal is in the rolls about 30 to 40 per cent of the total time of rolling and from 60 to 70 per cent of the time is required to handle the steel. A casual observation of the mill does not reveal this, but it is surprising how closely well operated mills approximate to the same figures. There has been a good deal of discussion regarding the ability of the motor driven mill to turn out tonnage and if an analysis is not made of the operation, one can be readily deceived when observing steam and motor driven mills in operation. A motor driven mill appears to manœuver slowly but a closer observation shows that it is operated in a different way than the engine driven mill, due to the fact that its speed can be more accurately controlled. Observation of operation frequently leaves the impression that the motor driven mill is not doing much work, due to the absence of noise or other indications of action. Actual records, however, show that the motor can give a good account of itself. I am quoting a few figures from different mills which indicate the output that can be obtained in practice. I do not believe that these represent, in any way, the limits of a motor driven mill, as development is still taking place which enables the

equipment to operate quicker and more efficiently, and I am sure that very much higher figures can be obtained than the ones I am quoting. I have not attempted to collect figures from all electrically driven reversing mills but am giving a few that have come to my attention. Possibly engineers from other plants that have electrically driven reversing mills have figures better than those I am quoting, but, at any rate, they will indicate what has been done.

At the plant of the Trumbull Steel Company, Warren, Ohio, there is installed a 36″ blooming mill which rolls ingots 20″x22″, weighing 6,700 pounds to 6¾″x6¾″ blooms in 13 passes. This mill has rolled 60 of these ingots in one hour and the operators feel that this figure can be improved.

Perhaps a better indication of the speed with which a motor can be handled is given by the machine driving the roughing stand of the 84″ tandem plate mill of the Brier Hill Steel Company. The following figures show a 12-hour and 24-hour record. It will be seen that there is very little difference between the 12-hour and 24-hour figures.

ROLLING RECORDS OF THE 84″ TANDEM PLATE MILL OF THE BRIER HILL STEEL CO.

	12 Hours	24 Hours
Number of slabs	1,659	3,270
Number of passes in roughing mill	7	....
Total charged weight, tons	373	716
Total finished weight, tons	315	518
Maximum number of slabs for one hour	220	....
Finished tons of 10, 11, 12 and 14 gauge U. S. Std	23	71
Finished tons of 8 and 9 gauge	13	435
Finished tons of 3/16 inch, No. 10 gauge	26	6
Finished tons of 1/4 inch and heavier	253	6

It will be seen that this mill averages, over a 12-hour period, about 16 passes a minute or less than 4 seconds per pass, which takes in all delays due to any cause. This mill has been in operation since September, 1919, and the performance has progressively improved as the men became familiar with the best methods of operation.

A third illustration, taken at our own plant, is that of

our universal plate mill which has rolls 30″ in diameter and can roll universal plate up to about 46″ wide. It is used for rolling skelp for our pipe mills and the material is, on an average, small for this size of mill. During the month of March, 1920, this mill turned out 23,014 gross tons of material and, as a matter of interest, I am giving details of how this was made up, from which it will be seen that the gauge was fairly light and the width not the best to secure maximum tonnage.

UNIVERSAL PLATE MILL PRODUCTION, MARCH, 1920

Sizes Rolled			Product Gross Tons	Slab Sizes, Inches	Slab Weights, Pounds
Width, Inches	Thickness, Inches	Length, Feet			
12	.375	Various	12	11¾ x 4	Various
15	.250	18′–19′	1,598	15 x 4½	1,480–1,240
15	.360	18′–19′	72	15 x 5½	1,790–1,440
18½	.310	18′–19′	510	18¾ x 5½	2,270–1,905
18½	.385	18′–19′	145	18¾ x 6	2,480–1,990
22	.290	19′–20′	1,003	22¼ x 5½	2,650–2,220
22	.437	18′ 6″–19′	25	22¼ x 5½	2,630–1,975
22¼	.255	19′–19′ 6″	174	22½ x 5	2,320–1,940
23½	.245	19′–20′	288	23¾ x 4½	2,390–2,000
23½	.285	19′–20′	2,816	23¾ x 5½	2,780–2,340
23½	.345	19′–20′	4,149	23¾ x 5½	2,820–2,270
25	.465	18′ 6″–19′	25	25½ x 6	3,165–2,385
28¾	.285	19′–20′	953	29¼ x 4½	2,850–2,290
28¾	.290	19′–20′	774	29¼ x 4½	2,900–2,325
28¾	.295	19′–19′ 6″	125	29¼ x 4½	2,920–2,350
28¾	.320	19′–20′	3,302	29¼ x 5	3,210–2,600
28¾	.330	19′–20′	1,038	29¼ x 5	3,280–2,630
28¾	.365	19′–20′	931	29¼ x 4½	2,925–2,210
28¼	.437	9′–11¾″	27	28¾ x 5	3,110–2,660
28½	.585	18′–18′ 6″	132	29 x 5½	3,330–2,190
32¾	.375	Various	74	33¼ x 5	Various
35½	.290	19′–20′	872	36½ x 5½	4,280–3,580
35½	.320	19′–20′	1,056	36½ x 4½	3,180–2,390
35½	.360	19′–20′	1,837	36½ x 5½	4,380–3,580
35½	.365	19′–20′	319	36½ x 5½	4,380–3,580
35½	.450	19′–20′	506	36½ x 5½	4,500–3,430
42¾	.345	19′–20′	251	36x 5–44½	2,160

Total gross tons rolled	23,014
Total hours worked	648
Total hours delay	79
Actual hours worked	569
Total slabs rolled	21,100
Good product	94.00 per cent.
Maximum day	1,101 Gross Tons
Minimum day	732 Gross Tons

It will also be seen that the delays were appreciable, which was due to the necessity of waiting for steel at times, roll changing, and minor troubles. We do not feel that this represents the limit of capacity of this mill and if necessary it could probably be boosted up to close to 30,000 tons per month by the addition of more heating furnace capacity and perhaps the elimination of some of the sizes which are entirely too small for a mill of this size.

These examples will give an indication of what is actually being done with the reversing mills that have already been installed. It has been my experience that factors outside of type of drive have in general limited tonnage. Much greater outputs can be obtained if necessary.

Delays

If we are satisfied with the possibility of rolling a desired tonnage, the next question is whether the equipment will operate continuously or at least with no more delay than encountered with steam drive. Here again the best answer is experience and in the following I am quoting figures from one or two mills which show the actual results obtained. The first electrically driven reversing drive to be installed in the United States was that of the 30″ universal plate mill in the South Chicago Plant of the Illinois Steel Company, which was put in operation in 1907. It was designed about the same time as the first equipment in Europe and went into operation a few months later. It must be appreciated that the electrical engineer was attempting to solve an entirely new problem with very little data and no experience, and later developments have shown that many of its constructional details could be materially improved. However, the history of this pioneer installation is of interest as it illustrates that even with an entirely new problem the time lost due to changes or breakdowns has not been serious. The major delays of this mill have been as follows:

November 10, 1907.—Mill shut down for one week to correct armature cross connections.

October 14, 1908.—Mill shut down to try out spare generator armature which had been purchased.

September 12, 1909.—Change of generator armature due to grounded coils.

October 24, 1909.—Generator armature changed due to some bars becoming unsoldered.

A novel design of generator was tried out in this installation which has not been used in subsequent jobs; this accounts for the particular troubles that caused the above delays. In 1911 there was a delay of a few hours caused by a slight short circuit on the commutator of one of the roll motors and in 1913 the mill was down for approximately 72 hours due to a grounded motor coil. In 1917 the generator armature was changed on account of a ground. The total of all delays, including those occurring during the development period, is approximately 525 hours out of about 100,000 hours that this mill has been operating, which I think is very creditable when it is borne in mind that it was a pioneer installation and was built at the time when the electrical engineer had not had the experience in building large equipments for steel mills that he has today. It might be mentioned that in 1920, after this mill had been in operation 13 years, no delays were charged against the drive, although the mill rolled in this year 20 per cent. more than in any other year in the first ten years of its life.

In March, 1913, The Steel Company of Canada put in operation a 34″ electrically driven blooming mill. This equipment embodied a number of important changes from the general design used for the Illinois Steel Company's mill and some control features which at that time were novel. A few days were lost, when the mill was first started up, in making a number of changes in the control. No particular effort was made to save time, as at that period the output of the mill was not urgently required. During

the last six years the total delay charged by the blooming mill department against this equipment has been about 12 hours and a detailed analysis of these figures shows that only about two hours have been due to delays caused by the equipment itself being down for any reason. These delays were made up of a few minutes at a time required to change a contact on a switch or some such minor matter, the remainder of the time lost was due to such causes as interrupted power supply, etc.

Another example is the 35″ blooming mill at Mark Plant. This mill was put in operation in April, 1918, and has run continuously to date. The total delay charged to the equipment is about 12 hours, the major part of this being due to interruption of power supply, which occurred when sand got into the boiler feed pumps and made it necessary to cut down station output until the difficulty could be corrected. Only a small part of the delays have really been due to the inability of the drive to operate the mill, perhaps not more than an hour or so. Such times that the mill has had to be shut down for electrical troubles have been made up of periods of a few minutes at a time for correction of minor difficulties involving adjustment of control equipment.

The examples I have cited I think are typical of what can be expected with reasonable operation and if accidents do not occur. Of course in the development of such equipments troubles have occurred which have been eliminated in later designs. Most of these troubles have been of a minor nature and the tendency has been towards simplification and so arranging the layout that an oversight or carelessness on the part of the attendants would not cause serious difficulties. However, accidents will happen in all plants and as an illustration I might mention some troubles we had with our plate mill drive. On one occasion it was found that the blowing equipment, upon which the cooling of the reversing motor depends, was not operating. This was not discovered until the

motor had become very hot, so hot in fact that the solder from some of the connections flowed. In later equipments, by simple means, provision has been made so that the motor cannot be operated if the blower is not delivering air to it. Nothing occurred immediately following this overheating, but about a year later one of the armature coils broke down and an examination of the machine showed that the insulation had been seriously injured by overheating. Temporary repairs were made which caused a delay of about 24 hours but a few weeks later another armature coil failed and it was decided that it would be wise to shut the mill down long enough to entirely rewind the armature, as it was felt that the winding had been so injured that more or less trouble could be expected from it, if this was not done. The motor was therefore put out of service and the armature completely rewound, the time required for the different operations being as follows:

Disconnecting from the mill and removing armature from motor...	12 hours
Stripping old coils and preparation for rewinding..................	34 hours
Rewinding..	50 hours
Reassembling the machine..................................	16 hours
Drying, varnishing and baking the armature.....................	96 hours
Total..	208 hours

As a precautionary measure it was decided not to start the machine until it had been thoroughly dried out and we were sure it was in as good condition as when originally installed. Facilities for drying and baking the armature, such as manufacturers have, were not available and it was necessary to experiment somewhat to find out the best way to do this. At least 60 hours could be saved, if such a mishap occurred again. If a spare armature had been available, the delay would not have exceeded 24 hours. This represents about as serious a failure as is likely to occur and I am giving its history so that some idea can be formed of what a really bad breakdown of such an equipment means in the way of delay.

Operating Labor

A factor in which our operators are particularly interested is operating labor. Most mills feel that their larger and more important drives, such as reversing mills, should have an attendant present to watch them, mainly as a precautionary measure. In the case of continuously running mills, there has been enough experience to show that this is not necessary and now it is customary for one man to inspect a number of machines and to take the usual meter readings for the mill records. When an operator is employed continuously to look after a drive, the usual practice is to put substation equipment under his control, as it is generally convenient to install converting apparatus in proximity to the main drive. These men have very little to do outside of occasionally looking over the machines and taking meter readings. The actual work in attending to a reversing blooming mill drive, for instance, I do not believe would exceed one hour per day. At the Mark Plant the blooming mill has been charged, for the years 1918, 1919, 1920 and 1921, an average of $393.00 per month. In the case of the reversing mill of The Steel Company of Canada, from 1913 to 1919, the average has been about $250.00 per month. The difference is mainly due to the fact that the figures for the former cover the period of highest wages in the mills.

Maintenance and Repairs

Electrical machinery requires maintenance as well as any other equipment. With intelligent electrical superintendents most of the expenditure is of a precautionary nature and repairs due to breakdowns become a very small item. As an illustration of the maintenance and repairs on reversing drives, the experience of The Steel and Tube Company of America can be cited. For the four years, 1918, 1919, 1920 and 1921, the maintenance and repairs for the reversing blooming mill drive averaged $184.00 per year. In the case of the reversing plate

mill drive previously referred to, the ordinary maintenance and repairs have averaged about $173.00 per year and the expenses in connection with the failure and complete rewinding of the armature totaled about $6,530.00. The maintenance of the blooming mill of The Steel Company of Canada has averaged since it was installed, for all purposes, about $1,280.00 per year. This higher cost compared with that at the Mark Plant is due mainly to the smaller size of the plant and a part of the difference may be ascribed to improved design of the later equipment. The supplies for operating these two blooming mills have averaged in each plant about $50.00 per month. These figures give an idea of what can be expected in the case of reversing mills. In the case of continuously running mills, the expenditures vary considerably, some mills paying practically no attention to their equipment and others carefully clean and revarnish their machines at intervals. In going over the figures of plants where freedom from breakdown is characteristic, it would seem that for motors from 2,000 to 3,000 H. P. we should spend perhaps $200.00 to $250.00 per year to keep them in condition. The cost will vary somewhat with the number of equipments the force has to look after, as with a larger plant the cost per machine will average less than in a smaller mill. Before leaving this phase of the subject, I would like to quote a statement of the electrical engineer of the Illinois Steel Company regarding the physical condition of their reversing mill which, as previously stated, has been in operation since 1907. The commutators of the reversing motors show about 1/16″ wear and the commutators of the generators show a wear of about 1/16″ for each five years of service. This would indicate a life for the commutator of the motor of about 180 years and for the generator about 60 years. The windings are in apparently about as good a condition as when first installed. At the end of 10 years some wear of the motor generator bearings was noticeable and as an insurance, spares were purchased, but to

date have not been installed, as in the last five years there has been no appreciable wear. The original motor bearings are in use and apparently will last indefinitely. Another example illustrative of the long life of electrical equipment when given good care which came to my notice, is the case of the 2,000 H. P. motors driving the light rail mill at South Chicago, Illinois. These machines were installed in 1906 and after about 14 years of service the Steel Company thought that perhaps it would be a good precaution to rewind them. A careful inspection by the manufacturer revealed no apparent deterioration and the recommendation was not to disturb them. These experiences indicate what can be expected with carefully operated plants.

In the foregoing I have given a few examples that will indicate to those whose duties do not bring them in close contact with electrical equipment what can be expected. It should be borne in mind that manufacturers have profited by their accumulated experience and many possible sources of troubles have been eliminated in recent installations. Another factor that will tend to secure even better results in the future is that a body of intelligent electrical engineers and attendants has been built up by our technical and trade schools, as well as by the principal manufacturers, from which our mills can draw good men. The electrician of the early development period was often very expert in making repairs but did little to avoid them. Today men are available who have been trained to avoid troubles.

Due to the many ways in which power problems can be solved electrically it is natural that frequently a difference of opinion exists as to the best way to handle particular requirements. In many of the cases, either one of a number of schemes will give entire satisfaction. In other cases, perhaps there is a best scheme, but other layouts are capable of satisfactory operation although not inherently as good as the best. In the following I am endeavoring to make what seems to me to be a fair state-

ment as to the present state of the art, which might perhaps act as a guide to those having to make decisions on equipments and who are not familiar with engineering details. I am not attempting to give the reasons for these statements as it would lead into too long a controversial paper.

Power Equipment

In building a modern plant we have the choice, in most localities, of either purchasing power from a Public Utilities Company or of building our own power plant. When we have sources of heat that would otherwise be wasted, this is usually sufficient reason for building our own plant. Public utilities, however, in many cases can make rates and give assurance of continuity of supply which make their power attractive.

Any modern power plant would only be built with alternating current units, as direct current involves too much expense for the distribution of large powers and has limitations from a generating standpoint.

In general, we have a choice of two pressures, 2,200 volts or 6,600 volts, either of which can be used directly with motors for main drive. Experience has shown that if the distribution problems are not too serious, 2,200 volts should be chosen, as the machines for this pressure are much freer from insulation troubles than those for 6,600 volts.

There are two frequencies in use in the United States, 25-cycle and 60-cycle. In the early days of electrification, when it was thought that most generators in the mills would be driven by gas engines and that the motors would be directly connected to the rolls, the 25-cycle system seemed to be the logical one to adopt. At that time, the means of connecting the higher speed motors to mills were not very satisfactory. Since then gearing and other mechanical features have been very materially improved, so that the great majority of mills installed

today use moderate speed motors geared down to the mill speed. The 60-cycle system has grown rapidly in favor during recent years and for main roll drive with proper connections is quite as satisfactory as the 25-cycle system. A further advantage is that the large power systems, which are gradually spreading over the country, are practically all 60-cycle and it is probable that in the future mills will find it profitable and desirable to purchase at least some of the power used. The 60-cycle system has a number of advantages as a greater range of motor speeds is obtainable and the machines are lighter and cheaper. The perfection of 60-cycle converting equipment, which was not available a few years ago, has materially changed the situation. The type of prime mover has an influence on the frequency adopted. Practically all gas engine driven units of the large size have been built for 25 cycles and there are some difficulties in the way of building 60-cycle units.

The choice of prime mover must be decided greatly by local conditions. In the early days the tendency was to use gas engines. The tendency today, however, is to use steam turbines and, as previously mentioned, improvements that are continually being made are reducing the difference in fuel economy between the two types. The first cost is an important item and one which seriously affects real economy.

To sum up, for the ordinary sized plant, the general practice today is to build a turbine station, generating current at 2,200 volts, 60 cycles, which is distributed direct to the mills.

Distribution

In the older plants most of the distribution is overhead. This is somewhat cheaper in first cost than the other alternative of placing all our cables underground, but it is not nearly as satisfactory. The best system is to use insulated lead covered cables laid in ducts

embedded in conduit which run to different consuming or distributing points. A great many of these ducts can be grouped together to run in such a way as not to interfere with any of the other parts of the plant. This leaves our yards entirely free from overhead obstructions. The use of overhead lines is always attended with danger, not only to life but also from an operating standpoint, as frequently the lines are damaged or torn down when running locomotive cranes around the plants. The use of an underground system eliminates all danger from lightning disturbances. The high tension underground distribution system at Mark Plant has not had a single failure in five years of operation.

Substation Equipment

We have the choice of either motor generator sets or rotary converters. The tendency is to use rotary converters, as they are lower in first cost and much more efficient. Motor generator sets give us the possibility of using substation equipment to improve power factor and in some cases they are justified. In a new electrification scheme, however, with proper design rotary converters are on the whole entirely satisfactory. It would seem that the greater loss in the motor generator set is an expensive way of improving power factor.

The development of automatic or semi-automatic control of substation equipment materially affects the question of substation layout and location. It is now quite feasible to control all our substations from the power house and the equipment is such that the only attention required is that which can be given by the motor inspector employed in the particular department where the apparatus is installed. This so reduces operating expense that we can afford to have more substations and save on our distributing copper. The freedom of layout gained thereby is a decided advantage.

Drives for Reversing Mills

There is only one practical system to use. It requires a fly-wheel motor generator set for supplying power to a direct current reversing motor connected to the rolls, and it is not likely that this scheme will be changed by future developments. Details of the machines vary somewhat with different manufacturers and it is only necessary to point out that very substantial mechanical construction is necessary on account of the shocks to which the machines are subjected. Reducing the cost by light construction is not justified. The control equipment is very important and the manufacturers have used a variety of schemes. There is more than one way of solving the problem, but the final result should be that skill on the part of the operator is not necessary. It should be possible for the operator to simply throw his control handle from one position to another and for the equipment to automatically perform the desired result immediately in such a way that the machines are not distressed. If the machine can carry a certain load safely, the automatic controlling equipment should be so arranged that during each manipulation the machine is loaded to its safe operating capacity but no higher. The nearer this ideal can be approached, the better the control equipment. The control equipment should also be such that it can be set to limit the load on the power house to any predetermined figure and to always operate at this point. To have a really satisfactory equipment it is necessary to closely approach this ideal and the best equipment is one that does it with the simplest apparatus. Improvements in the future will probably be towards making the machines cheaper due to better design, but the main development will be towards simplifying and improving the control equipment to give an operation approaching the ideal as nearly as possible. Reversing mill equipments as made by the two principal manufacturers, have proved adequate and reliable. Provision should be made in the lay-

out to insure that the machines are properly ventilated at all times and a failure of the air supply should shut down the equipment before it can be injured. The electrical design is in general best left to the manufacturer. For instance, whether single or double armature motors are used is immaterial unless it involves a machine of more than usual voltage. When the power required is greater than can be supplied by a single generator fly-wheel set, the tendency is to run two generators in series on one motor. If this involves using a total armature voltage of 1,000 to 1,500, it is preferable to use two motors and connect all the machines in series which, if they are arranged alternately, generator and motor will limit the voltage at any point to that of one generator only. It is preferable not to exceed 750 volts if possible. It is advisable to supplement the usual ring lubrication with a gravity oiling system to all the bearings of the fly-wheel set and reversing motor as this is an insurance that is worth the small expenditure. Water-cooling of the fly-wheel bearings is sometimes adopted and is desirable if they are heavily loaded.

Constant Speed Drives

For this service alternating current motors are generally used, direct current motors being used only in some of the older plants where only direct current is generated. These machines have reached a high state of development, and improvement during recent years has only been of a minor nature towards reduction of cost.

Adjustable Speed Drives

As any large power station involves generating alternating current, the problem of building an alternating current equipment, the speed of which could be adjusted for different mill conditions, presented a serious problem for many years. During the last ten years it has been solved satisfactorily in two different ways. The first

scheme uses an alternating current main motor and an alternating current auxiliary commutator machine. Such machines have involved some technical difficulties which have been successfully overcome. These equipments are arranged so that the driving motor can be run above or below its synchronous speed which reduces the size of the auxiliary apparatus required. Should the auxiliary apparatus fail, the driving motor will run at the middle speed. This characteristic is probably of little value as it pre-supposes failure of equipment which normally should be quite reliable. This scheme provides a drive which inherently develops the same torque at any speed so that the output varies with the speed.

The second scheme that has been adopted uses an alternating current motor on the same shaft with which there is mounted a direct current motor and there is an electric connection between the two through a rotary converter. This scheme uses ordinary types of machines which have been highly developed. While it is possible to run the set above the synchronous speed of the alternating current machine, the speed cannot be regulated at points close to the synchronous speed, or say within plus or minus 8 per cent, and it cannot be brought above the synchronous speed except under light load such as might be due to the friction of the mill alone. Therefore it is generally arranged, so that the motor, without auxiliary equipment, runs at the maximum speed and the speed is reduced through the regulating equipment. This scheme has the natural characteristic of developing an increasing torque as the speed is reduced, the power remaining constant throughout the speed range.

There are many installations of both of the above described arrangements giving thoroughly satisfactory results and very frequently price will be the determining factor as to which one is used. Another arrangement is sometimes used and under certain circumstances provides the best means of securing an adjustable speed drive. It is to use a rotary converter to change the alternating current

to direct current and to drive the mill with a normal direct current motor. This scheme is advantageous where a large speed range is required, particularly on 60 cycles.

The efficiency of the first two schemes is approximately the same. The use of a rotary converter and direct current motor involves a loss of usually from 3 to 5 per cent more than that of the first two schemes.

Adjustable Speed Drive for Tandem Operation

Where a number of motors are used to drive rolls in tandem and the metal is in the different stands simultaneously, the relative speed of the motors must be maintained the same, although different conditions will require the speed of all to be raised or lowered. This problem is solved very satisfactorily by the use of direct current machines, the desired characteristics being obtained by special control equipment. There are several ways of accomplishing the desired result which are entirely satisfactory.

Auxiliary Drives

Experience has shown that the best practice is to drive auxiliaries that start and stop frequently with direct current machines, and also to use direct current where it is desirable that the speed increase if the load is reduced, as for instance on cranes. It should be used in all cases where the speed has to be adjusted for different conditions, such as, for instance, machine tools, etc.

Alternating current motors are used in cases where the machines run continuously or have to start infrequently, such as for shears, saws, blowers, etc. The use of alternating current for driving motors, which start and stop frequently, has been tried but general experience is that the direct current machines handle the work better and its characteristics are better suited to the requirements.

Motors for auxiliary equipment have been standardized by the principal manufacturers and designs are

thoroughly reliable. Minor details are being improved upon from time to time but no radical changes are to be anticipated. Progress is still being made in the development of controlling devices.

In the past the choice of motors for auxiliaries and the gear ratios has been largely a matter of guesswork. It is not necessary that this be so, and a little preliminary study will usually enable a layout to be made that will operate satisfactorily from the start. Such a study will not only save many changes, but frequently will also indicate how the electrical equipment can be simplified so as to consist of a few simple units only.

The Chairman (Mr. William A Rogers): The first discussion of Mr. Sykes' paper will be by Mr. David M. Petty, Superintendent of Electrical Department, Bethlehem Steel Company, Bethlehem, Pa.

Discussion by David M. Petty

Superintendent, Electrical Department, Bethlehem Steel Company, Bethlehem, Pa.

In the discussion of this paper I want to call attention to three phases of steel plant electrification that Mr. Sykes has omitted and then to take up his paper in the reverse order so as to finish with the power plant as the vital spot of the plant circulating system.

The three subjects not referred to by Mr. Sykes are:

(1) The electric steel furnace.
(2) The electric heating furnace.
(3) The electrification of steel plant railway.

The electric furnace for making steel has made wonderful strides in the past ten years until it now bids fair to put the old crucible furnace out of business. The arc furnace has progressed much more rapidly than any of the other types of furnaces until there are now more than 350 arc furnaces in the United States, whereas in 1912 there were not more than twenty (20). The induction type furnace has been much slower in its development

due to the great difficulty in securing proper refractories, but there is every indication at the present time that in the near future the induction furnace will be in more common use. The metallurgist appreciates the value of the electric furnace because of the ease with which the metallurgical reactions can be controlled and the intense heat which is available, as well as the absence of any gases to influence the reactions in the refining process.

Heating of steel in electric furnaces where the heat is generated by resistance has made great progress since the introduction of nickel chromium wire, which not only has a high melting point but offers great resistance to oxidation at high temperatures. The heat treatment departments of the steel plants appreciate this type of furnace on account of the ease with which the temperatures of the furnace can be controlled, either manually or automatically, by the use of pyrometers. The heating of steel bars by passing the current through the bar will apparently be the next step in the electric heating furnace. This method offers great possibilities owing to the fact that the increase of the temperature in the bar is uniform throughout any given cross-section, thus eliminating internal stresses caused by uneven heating. Uniform heating throughout the cross-section permits the steel to be brought up to the desired temperature in a much shorter time than is permissible if the heat must be absorbed by the steel from the outside inward.

The traffic density on the average steel plant transportation system is heavy compared to the average railroad. The great railway systems have found it economical to electrify their terminals where traffic density is great, also those parts of their systems where heavy grades are encountered. It would seem, therefore, that we should eventually electrify our steel plant railways. The obstacles to be overcome are many, but it seems to me that these obstacles are only different from and not greater than those which have been overcome in other

lines of electrification. It is generally admitted that the steam locomotive is a very uneconomical machine when compared to even a steam engine operating under more favorable circumstances and the efficiencies of the electric locomotive as compared to the steam locomotive can hardly be mentioned in the same class.

Auxiliary Drives

Mr. Sykes has pointed out the fact that the power consumption of the auxiliary drives is a considerably larger portion of the total power used in the steel mill than it is generally understood to be. A great many mills have an even higher percentage than 18½ as shown in this tabulation. The fact that the auxiliary drives are made up of many small motors tends to create the impression that this is an unimportant phase of steel plant operation. It should always be remembered that failure of one of the more important auxiliary drives stops production just as definitely as a failure in any part of the main drive of the mill, whether steam engine or motor.

In the laying out of new mills the auxiliary drives should receive very careful attention so that repairs can be made in the shortest time possible, and also load characteristics of the machines to be driven should be studied so that a motor of the proper characteristics can be applied, because no matter how rugged or how good the design and workmanship of the motor is, if it is improperly applied the service rendered will be unsatisfactory. Too little attention has been given in the past to the subject of inertia in the moving parts of auxiliary machinery in many mills and the failure of mills to produce tonnage can often be traced directly to the mis-application of the auxiliary motors or controllers.

On a given mill as many motors as possible should be interchangeable so that a small number of motors will be needed as spares. At this point I would like to call attention to the work of the Association of Iron and Steel Electrical Engineers who have for several years been

trying to get the motor manufacturers together so that a mill motor of a given horse power of one company will fit into the space occupied by a similar motor of another manufacturer. It is readily seen that standardization to the point of uniform principal dimensions would be of great value to the steel mills, and I would suggest that the American Iron and Steel Institute lend its support to the Association of Iron and Steel Electrical Engineers in this work.

On account of the fact that the power consumed by the auxiliary drives is divided into many small parts as compared to the main roll drives or larger units, the danger of wasting power at this point is much greater. Excess friction in the roller lines, screw-downs and other auxiliary apparatus around the mill not only causes motors to be overloaded and burned out, but also costs real money in excess power required to drive these various auxiliaries. Few mill men realize that 100 H. P. extra load, due to any cause whatever, if operated 26 days in the month and 24 hours per day costs $300.00 per month, if power is charged to the mill at ½ cent per kilowatt hour. I believe the electrical engineers in the steel plants will be more successful in having excessive friction loads removed if they will state the trouble to the mill man in terms of dollars rather than in terms of kilowatt hours and broken down electrical apparatus.

The subject of auxiliary motors should not be passed over without giving consideration to the subject of anti-friction bearings. Here again the Association of Iron and Steel Electrical Engineers is endeavoring to work out a satisfactory solution to the problem of placing roller bearings or ball bearings in the mill motors. It has been determined that a large percentage of motor failures are caused by oil getting in the windings of the motors from their bearings. It is felt that if the ring oiler bearing can be eliminated from the steel mill motors a great many delays will be avoided.

The control apparatus for auxiliary drives should be

laid out with the smallest complication possible so that adjustments and replacements can be made in the shortest time. On particularly important drives it frequently is good engineering to provide duplicate controllers, and where a large number of like controllers can be grouped together it is good practice to provide one or more complete spares so that a disabled controller can be cut out of service without interrupting operation of the mill.

Main Roll Drives

Mr. Sykes has covered the subject of main roll drives very completely, and I wish to bring out only one additional thought. It concerns the question of spares for the main roll drives.

For an engine, spare cylinders, crank shafts, connecting rods, main bearings, etc., are usually carried right in the mill. For large continuously running induction motors spare coils can be carried and the problem of making replacements in the main roll drive motor is relatively simple, but for the direct current motors, such as used on reversing mills, the problem is considerably more difficult. To replace a coil in the armature of one of these large motors requires considerable preliminary work in dissembling the motor, and the danger of the trouble being spread over a wide area in the armature is greater than is the case with induction motors, thus making it more important to provide ample crane facilities for handling the heaviest parts of these large reversing mill motors, and the layout of the drive itself should be such that replacements can be made in the shortest time possible. In the case of blooming mills, which take the entire product of the open-hearth plant, it may prove to be good engineering to provide spare armatures. When two or more mills of similar design and capacity are electrified the armatures should be interchangeable even if the smaller mill is overmotored so that one set of spares will serve for a group of mills.

The dangers above mentioned are appreciated by the

designing electrical engineers and every precaution is usually taken in the design of a machine to eliminate the possibility of failures. The operating electrical engineer in the steel plant should not fail to provide frequent inspections of the motors and promptly repair any parts which appear to be giving away.

To supplement the figures given by Mr. Sykes in rewinding one armature of a reversing set, I would add that at the Lehigh Plant, Bethlehem Steel Company, two such armatures were simultaneously rewound in 13 days from ingot to ingot. This time could possibly be reduced to 10 days of 24 hours each.

The production of the mills driven by continuously running induction motors is no longer a matter of discussion and it is generally conceded that whenever a steam engine is replaced by an induction motor the production of the mill is materially increased. Production, however, on an electrically driven reversing mill is still in the discussion stage. As additional evidence to that given by Mr. Sykes, showing the production ability of electrically driven reversing mills, the following figures are given: the 40″ blooming mill in the Maryland Plant, Bethlehem Steel Company, has rolled 330 tons of 10″ x 40″ slabs in one hour from 21″ x 43″ ingots, weighing 16,500 lbs. each, and 151 tons of 8″ x 8″ blooms in one hour from 20″ x 24″ ingots weighing 8,000 lbs. each.

The power consumption when rolling 8″ x 8″ blooms was 14.6 K. W. H. per ton; and when rolling 5″ x 28″ slabs from 21″ x 43″ ingots, the power consumption was 7.7 K. W. H. per ton. This consumption includes all power consumed by the exciter sets and blowers for ventilating the motor. For the month of April, 1922, this mill rolled 31,686 tons with a power consumption of 15.7 K. W. H. per ton, approximately equal quantities of blooms and slabs.

With the electrically driven reversing mill it is possible to operate with at least one man less in the operating pulpit than is the case with engine driven mills, it

being entirely practical to eliminate the engineer. For some time we have been operating our blooming mills both at the Lehigh Plant and the Maryland Plant with two men, the roller not only handling the screw-down and tables, but also the main rolls. The manipulator man handles the same apparatus as with the steam engine driven mill. The rollers in general have not objected to taking on this additional duty, but feel better satisfied than when they operated with an engineer, because they have the mill, as well as the tables under their own control without having to signal to the engineer.

Generation of Power in the Steel Plants

In the matter of distribution of power in steel mills it is sufficient to say that in general the distance over which power must be transmitted makes it entirely possible as well as advisable to eliminate step-up and step-down transformers so far as the main roll drives and large motors are concerned. The voltage of generation should be the voltage of distribution and the voltage of all the large motors say from 250 H. P. up. If the distances are short and the total capacity small, 2200 volts will be sufficient and advisable, but when the total capacity of the power station reaches 20,000 to 30,000 K. W., in general, 6600 volts will prove to be more satisfactory.

So far as transmission is concerned, if the local conditions do not make the cost prohibitive, underground transmission is to be preferred, but it should be remembered that overhead transmission systems can be designed and laid out which will operate entirely satisfactorily. The only hazard which the properly designed overhead transmission system has in addition to that offered by the underground system is lightning, and by the liberal use of well known protective devices the damage by lightning can be reduced to practically zero.

The advantages which the overhead systems have as compared to the underground systems are as follows:

The insulation of the overhead system is porcelain, whereas the insulation of underground systems must be rubber, varnishes and fabrics which depreciate with time and will withstand temperatures only within limited ranges. The overhead system can be enlarged almost at will, whereas additions to the underground system are difficult to make and more expensive.

In discussing the prime movers for the steel plant power station, Mr. Sykes makes the statement that the gas engine power station costs fully twice as much as the steam turbine station. I cannot agree with this comparison. The latest data on this subject shows that the gas engine station of 15,000 to 20,000 K. W. capacity can be installed for $130.00 per kilowatt and larger stations for a figure lower than this. A steam turbine station 15,000 to 20,000 K. W. capacity fully equipped with spares will cost at least $90.00 per kilowatt installed if the boilers, water handling equipment, etc., are included.

One advantage of a gas engine station made up of 3,000 or 4,000 K. W. units is the fact that only 3,000 or 4,000 K. W. additional capacity is required to provide a spare unit, whereas with 15,000 or 20,000 K. W. steam turbine units a unit capable of replacing the largest size unit in the station must be carried to fully protect the station against a power shortage at full load.

Mr. Sykes also makes the statement that not more than 15 per cent. better economy is offered by the gas engine as compared to the steam turbine. I cannot agree with this figure. I think that the advantage of the gas engine over the steam turbine is not less than 33-1/3 per cent. 100,000 cu. ft. of blast furnace gas carrying 100 B. T. U. per cu. ft. used in the modern gas engine will produce 600 K. W. H. The same amount of gas used in a modern steam boiler and in turbines of sizes suitable to the steel plants will produce 450 K. W. H. Furthermore, it should be remembered that all of the known economies of gas engine practice are not in general use in the United States today. We are using only a small

portion of the heat contained in the exhaust gases for heating feed water. This item can easily be extended to a point where a much larger volume of water can be heated and used for such purposes as heating buildings; the same idea can be developed still a little further and can be used for making steam. Such practices as these have been in use in foreign countries for some time, and will come into use in this country when the cost of a heat unit increases sufficiently to warrant the investment.

The operating and repair costs of gas engine stations are ordinarily considered to be excessive. The following figures taken from the Power Station at Lehigh Plant, Bethlehem Steel Company, show these costs to be very low:

TABLE SHOWING OPERATING COST OF A GAS ENGINE POWER PLANT

Capacity of plant, six 3,000 K.W. units	18,000 K.W.
Energy generated in one month	8,591,000 K.W.H.
Operation in engine hours	2,953.5
Average load per engine	2,905 K.W.
Maximum average load per engine	3,500 K.W.
Maximum 15-minute load per engine	4,000 K.W.
Load factor (average divided by maximum load)	72.5%
Capacity factor (average load divided by capacity)	55.0%

	Cost per K. W. H.
Fuel, 1,143,288,000 cu. ft. of gas, average 94 B. T. U. per cu. ft. at .0094 per 1,000 cu. ft.	.00158
Labor, including switchboard operators, engineers, oilers, superintendence, etc.	.00038
Repairs, including renewals, tools, miscellaneous supplies and labor in repairs	.00041
Water for cooling, oil, waste and packing, including cooling pond expenses	.00021
Gas cleaning, including water, labor, repairs and power	.00037
Total operating cost	.00295
Credit feed water heated with exhaust gases (installed on four engines only)	.00033
Net operating cost	.00262

The question of depreciation in gas engines often arises and is frequently referred to as being excessive. The fact that a large gas engine station in the Gary Plant has been running fourteen years is sufficient evidence

that the gas engine has a long life. I am sure that the operators do not feel that these engines have reached the limit of their usefulness.

In addition to the gas engine and steam turbine as prime movers in the steel plants, the Diesel oil engine should be given consideration. Engines of this type are now available in units, the capacity of which can easily be 2,000 K. W.

The Diesel engine offers many advantages as a stand-by unit. It requires no boilers to be kept under steam, no coal or ash handling equipment, no fuel storage facilities, except a tank for storing the required amount of oil. It can be started quickly and will take full load almost immediately. The cost of power made on such units will not be out of line when compared with the cost of the steam turbines taking steam from a coal fired boiler house.

It would seem to me that the ideal layout of a steel plant from the power standpoint would be a gas engine power station of sufficient capacity to carry all of the steady load which in general will be approximately 80 per cent. of the total load. The gas engines in this case would be operated so as to run at practically full load all the time. The remaining part of the total load which is fluctuating in character could be taken care of by anyone of three different methods:

(1) By a steam turbine. This method should meet all the requirements if the supply of gas is plentiful; or the price of coal low, if it is necessary to burn coal for making steam.

(2) By Diesel oil engines. This method should prove to be satisfactory as well as economical when total gas supply is limited and the price of coal relatively high compared with the price of oil.

(3) By purchasing power from a Public Utility Company. This plan offers several advantages when the territory in which the particular steel plant is located is served by a large Public Utility Company whose power

rates are reasonably low, and it should prove to be especially attractive if the power company can economically take power from the steel plant gas engine power station at such times as the steel plant load is light. This arrangement permits the gas engine station to operate at full capacity 365 days in the year and it can therefore take the gas from the blast furnaces where it is available for 365 days in the year.

Operation of the steel plant power station in parallel with a central station brings up the question of frequency. It should be remembered that with modern gas engines and alternators no difficulties at all are experienced when operated at 60 cycles, and if other local conditions do not demand 25 cycles, 60 cycles should be adopted as the frequency of a new plant. The real problem is how to convert our 25-cycle steel power systems to 60-cycle plants so as to more easily tie in with the large power systems.

In general the problem of generation of power in steel plants should be approached with one eye on the operating cost of today and one eye on the operating cost of the future. Economies which are not good economical engineering today may be common practice 10 years hence, and certainly any practice which tends toward the conservation of the natural resources of each individual steel company as well as those of the world are worthy of serious consideration. I believe it is recognized that among other things the coal supply of each company as well as of the world has a rather definite limit and that as consumption increases the supply decreases, hence the unit value of such reserves will inevitably increase. This should be taken into consideration, whenever laying out a power station, so that the maximum number of kilowatt hours will be obtained from each unit of coal used in the industry.

The Chairman (Mr. William A. Rogers): The second discussion of Mr. Sykes' paper will be by Mr. R. W.

Cousins, Electrical Engineer, Indiana Steel Company, Gary, Indiana.

Discussion by R. W. Cousins

Electrical Engineer, Indiana Steel Company, Gary, Indiana

Mr. Sykes brings out in the first part of his paper on "The General Effect of Electrification of Steel Mills Upon Their Operation" the statement that the apparent lack of interest in electrical subjects by some executives and operators is probably due mainly to two factors:

(1) The layman feels it is somewhat mysterious.

(2) The non-electrical man is troubled with the vocabulary of this branch of engineering.

I feel exactly as Mr. Sykes. The electrical engineer finds it hard to discuss present or future operations and installations with the equipment operators. No difficulty is experienced in discussing mechanical conditions, as most of the things discussed are more or less apparent. Possibly the misunderstanding is partly due to both; but, however, a closer understanding will facilitate matters in the end. Laying aside all controversies due to lack of understanding, the progress in the development of electrification of steel mills is a splendid example of what cooperation can accomplish.

In 1891 the first electric motor was installed in a steel mill. American steel making today has the distinction of being one of the most highly developed industries in the world. The early progress was slow, because the electrical manufacturer had not realized the conditions in the steel mills, and had not built his first motor to stand this class of service. Today we have all classes of electrical apparatus designed to operate satisfactorily in this service.

The application of electric drive secures the most practical and economical method of power generation. A central station comprised of electric generators will show a decided saving in fuel consumption and general expense compared with individual steam driven mills.

The average load on rolling mills is from 30 to 40 per cent. of normal or connected load. By supplying power from a central station the load from the different mills will overlap and the load upon the station house becomes more uniform. The generating units will be operated at their full load rating. This is made possible by being able at all times to operate the required number of units.

I am giving below the average load in per cent. of rating on gas engine driven generators at Gary. This load is based on the size of unit and exact time unit was in service.

Period	No. of Generators	Size	Average Load
January to April, 1922, inclusive..	17	2000 K.W.	92%
	17	3000 K.W.	88%

Operating in parallel with these generators are two 7500 K. W. steam-turbo units; these are used for regulating purposes. Connected to this station is approximately 267,300 horsepower, of which approximately 223,300 horsepower is for the Gary plant of the Illinois Steel Company. The average generating capacity on the bus to take care of this load is 92,000 horsepower, giving a load factor of 34 per cent. To operate these mills or units as separate installations would require a much greater aggregate capacity of generating equipment.

Mr. Sykes states that improvements are being made in steam turbines to reduce the difference in economy between turbines and the gas engine. The gas engine for power generation has also advanced and I feel that the overload capacity and regulation of these machines will be greatly increased in the near future.

As a matter of interest I am giving figures of the number of tons of ingots produced for the year 1921 and the power utilized in the plant in making and rolling same.

	Open-Hearth Tonnage	K. W. Hours used in Plant
Year 1921..................	1,792,409	231,493,485

Or at the rate of 129 K. W. Hours per ton,

The kilowatt-hour figure given is the total produced less the amount of 100,815,915 kilowatt-hours furnished the outside plants, making a grand total of 332,309,400 kilowatt-hours produced. This amount of power produced ranks with some of the largest central stations.

We all agree that the only economical method of furnishing power to a community is by means of central station installations. Our output shows the necessity of, or I may say the operation made possible from, the electrification of the steel mills, the kilowatt-hours depending solely on the rate per year of product.

It will be interesting to note that our rail mill and billet mill each require an average of approximately 13,000 horsepower, making a total of 26,000 horsepower. Operating one mill alone requires six 2,000-K. W. generators. Both mills can be operated from a central station with nine 2,000-K. W. generators, making a saving of 25 per cent. in power equipment on that required when operating as separate units. From the above and other figures available we are ready to accept the statement that the steam consumption can be reduced fully 50 per cent. if the mills are electrified and power furnished from a central station.

The use of electric power greatly reduces maintenance and requires less supplies. We all remember, when the steam engine was in general use for steel mill drives, the number of men required for Sunday repairs. Each mill had its own crew and certain men from the general shop were added, the foreman looking out to see that so-and-so would be out to scrape this bearing or tighten up this pin or rod, as he was about the only man who could do the particular job in question, having performed the same task many times before. With the electrification of the steel mill this has entirely disappeared. The Gary rail mill has installed 24,000 horsepower on the six main drives; three drives are driven each by one 2,000-H. P. motor and three are driven each by one 6,000-H. P. motor. Operating these six motors are one first and one second

operator on each turn. These men look after the current repairs and operation, all general cleaning of both motors and control apparatus, as well as all oiling of motor bearings. Most of the general repair work is done during the week days, very little work being done on Sunday. Twice a year each motor is moved over so as to permit getting at both the stationary and revolving parts, and are given a thorough cleaning and are then painted with insulating varnish. This work necessitates calling upon four or five extra men. Work is done over the week-end shut-down, leaving the motor ready for Monday morning start. This method of cleaning is followed throughout the plant. The mill delays charged against these motors has been practically nothing, such delays when occurring being of very short duration.

Electric drive means an economical and convenient method of power distribution. The line loss in the average steel plant is very low, as in most cases the distance is short and current value so high that the line is figured for current carrying capacity of cable, and large amounts of copper are not required to keep the line losses within reasonable amounts. And right here I want to say that I heartily agree with Mr. Sykes as to installing all feeders underground.

The Gary Plant is operating over 210,000 feet of 3-phase, paper-insulated, 6,600-volt, lead-encased cable installed in ducts embedded in concrete. Each cable is so installed that it is an outside cable. Such construction prevents pocketing any cable in the duct system. Each mill has its own feeders or set of cables running from the power house.

The Gary 12-inch strip mill, which was put in operation March 1, this year, is another mill made possible by electrification. The mill consists of twelve stands of rolls, passes 1-2-3-4-6-7-8-9-10 being driven by one 2,750 H. P., 262-214-167 R. P. M. variable speed motor; pass 5 is driven by means of a 300 H. P., 333-250-183 R. P. M. variable speed motor; pass 11 is driven by means of a 750

H. P., 360-300-222 R. P. M. variable speed motor, and pass 12 is driven by means of a 750 H. P., 473-375-278 R. P. M. variable speed motor. In designing this mill it was found impracticable, on account of some sections, to gear all stands to one drive, as it is necessary to have the speed of some of the passes under control of the mill operator. Speed regulation is by means of the Scherbius system, giving constant torque, horsepower varying as the speed.

The above described mill comes under the class of adjustable speed drive for tandem operation as stated by Mr. Sykes on page 148. However, alternating current motors are used instead of the direct current motor. This equipment as installed permits operating at middle speed in case of failure of any of the auxiliary apparatus. It has been my experience that more delays are caused by failure of the auxiliary equipment rather than of the main motor. The equipment consisting of four roll motors and regulating apparatus is taken care of by one motor tender on each turn.

Mr. Sykes states, "In any discussion of economy we must be careful to distinguish between theoretical figures and actual operating results from the energy in gas or coal to the mill coupling during a month's or a year's operation and the only teacher of any value is experience." I fully agree with him but would go a step farther and take into consideration the operation between the mill coupling and the rolled product. This depends in a great measure on how the power is applied to the coupling.

Our 160-inch plate mill is, as stated, driven by a 7,000 H. P. motor and same can be made to take instantaneous peaks of 20,000 H. P. However, this results in severe shocks to the mill, as well as to the power house and cables, and even the coils of the driving motor are subjected to high mechanical stresses due to the corresponding high current values at this peak load. By means of permanent secondary resistance in the motor circuit and control apparatus for further changing the character-

istics of this motor, we run at the maximum fly-wheel effort, getting the motor back to mill friction speed instantly if motor has been pulled below a predetermined speed. Such methods of control have been criticised by some as reducing slightly the efficiency and power factor of the motor; however, we get a more gradual application of power necessary to roll, thereby resulting in a saving to the mill in cost of repairs and the efficiency of all equipment is increased.

As to operating labor, this policy as stated by Mr. Sykes has been followed out at the Gary Works of the Illinois Steel Company, installing converting apparatus in such locations where it was absolutely necessary to have an attendant for roll train motors, thereby resulting in a saving in the operating cost as compared with such separate installations requiring a special attendant. The automatic substation to my mind has not been simplified sufficiently to warrant its adoption in the steel mills.

Mr. Sykes states that 2,200 volts should be chosen for distribution pressure. I do not agree with him, unless the plant uses very small units. Aside from the little gain in insulation troubles due to the lower voltage nothing is gained, as we have heating of switches, breakers, larger cables, etc., to contend with. Even on our 6,600-volt system this is of considerable moment. The insulations used today on both high voltage cables and machines cause very few delays. I would recommend the higher voltage if underground cables are used.

As to the question of 60 versus 25 cycles in the steel industry, a great deal has been said for and against each. About the time substations began to be generally used for street railway work, the 60-cycle rotary was used; however, this did not prove successful. The 25-cycle equipment began to appear and better results were obtained. Almost all of the generating equipment was driven by means of reciprocating engines of comparatively slow speed. With the introduction of the steam turbine, which permitted high speed, naturally 60 cycles to the general

public load was desirable. Small high speed 60-cycle motors were advocated on account of being cheaper than 25-cycle. As the frequency is a function of the speed and the number of poles, the higher speed appears on the surface to be the ideal speed. For equal power factors the 25-cycle motor is smaller and cheaper than the 60-cycle motor. At the higher speeds the power factor of the 60-cycle motor improves. On the basis of equal costs of motors we should take into consideration the cost of apparatus for power factor correction when using 60-cycle motors. I cannot say whether or not that on account of central stations going to 60 cycles this will influence the steel mills to adopt 60 cycles so as to be able to purchase power.

It has been stated that the adoption of 25 cycles for the Gary Plant had a very decided influence in fixing 25 cycles as a standard for steel mill work. If 60 cycles had been chosen at that time it is probable that steel mill electrification would have been greatly handicapped. Granting that there has been a vast improvement in 60-cycle apparatus, I feel that where slow speed motors are used that 25 cycles is the ideal frequency. The type of the prime mover in the generating station will govern to a large extent the frequency of the system for steel mill work.

Mr. Sykes makes the statement that the use of alternating current for driving motors which stop and start frequently has been tried, but general experience is that the direct current machines handle the work better and their characteristics are better suited to the requirements. About 75 per cent. of the auxiliary drives at our coke plant, axle and merchant mills, totaling 40,000 horsepower, are driven by mill-type alternating current motors. The remaining 25 per cent. are constant speed induction motors. These last mentioned drives would be used no matter what type of motor was used for the other drives.

It has been my experience that for cranes doing such

class of work as that found in merchant mills, and for driving tables, etc., in merchant mills, we get better operating cost and fewer delays both electrically and mechanically by using the alternating current mill-type motor. Due to the characteristics of the motor, the operator is not able to punish the equipment to the same extent as with the direct current motor.

Two of the greatest objections to the alternating current mill-type motor have been the small air gap and closed-slot rotor construction. Our new 20-inch and 12-inch strip mills, which went into operation this year, have all auxiliary drives driven by alternating current mill-type motors having larger air gaps and open-slot rotor construction. At my request these changes were made by the manufacturer, the designing engineer stating at first that it was impossible to build these motors as suggested, but when shown that the changes would result in only a slight decrease in theoretical efficiency, and a large increase in operating or all-day efficiency, the changes were at last made, and we expect to see great returns in the operating of these motors.

In conclusion it may be said that there is no good general solution to the problem of electrification of steel mills. Each case must be handled on its merits, taking the future tendency and growths into account.

No matter what type of electrical construction has been used, or will be installed in the future, electrification of the steel mills has made the operation what it is today.

The Chairman (Mr. William A. Rogers): The second paper on the program of this afternoon's session is "The Importance of the Iron Ores of the Adirondack Region," to be read by Mr. Frank L. Nason, Consulting Geologist, Witherbee, Sherman & Co., New York.

THE IMPORTANCE OF THE IRON ORES OF THE ADIRONDACK REGION

Frank L. Nason

Consulting Geologist, Witherbee, Sherman & Company, New York

In 1916 the American Iron and Steel Institute published a paper by Mr. Frank S. Witherbee, President of Witherbee, Sherman & Company, on "The Iron Ores of the Adirondack Region." This paper leaves little to be said as to the known areal distribution of the ores and their amenability to a high degree of concentration. The estimate of 1,100,000,000 tons of available ore of milling grade, while conservative, is a rather arbitrary statement with few supporting facts. As to the amenability to magnetic concentration, this is also a more or less arbitrary statement with few supporting facts. This is not adverse criticism, nor is it intended to detract from the solid value of Mr. Witherbee's paper.

The present paper is really supplementary to the senior paper, giving supporting details as to the magnitude of the deposits, the general grades in iron, illustrations of their amenability to magnetic separation, and the general costs of mining and milling.

For assistance in compiling the present paper, consent to publishing approximate costs of mining and milling, the methods of "trying out" ores from unworked and undeveloped mines, etc., the writer is indebted to Messrs. Witherbee, Sherman & Company, Mr. Lewis W. Francis, President; The Chateaugay Ore and Iron Company, Mr. W. H. Williams, Senior Vice President; The MacIntyre Iron Company, Mr. A. Thompson, Treasurer; Mr. J. R. Linney, Mr. A. M. Cummings and others.

Structure of the Ore Bodies

Much has been written about the origin of the rocks enclosing the magnetic iron ore bodies as well as of the origin of the ores. This is mainly speculative and is of little or no economic value. Speculation is confined to the straight magnetic ore bodies and their enclosing gneisses. There is, however, a sharp division between

Fig. 1—Shaft head, shaft 1,600 feet deep; miners' change house in foreground; magnetic separating plant, capacity 1,500 tons of crude ore daily, in background; Chateaugay Ore & Iron Company, Lyon Mountain, N. Y.

the ores and their enclosing rocks. There is no speculation on this point. There are two classes of ores, one, titaniferous, containing as much as 12 per cent. or more of titanium and 50 per cent. iron; the other, having a variable iron content but with no titanium. The titaniferous ores occur in well recognized intrusive rocks, gabbros and anorthosites. These ores are generally recognized as being magmatic segregations from the emptive mass. The ore bodies, so far, exist as masses of varying size.

They are isolated masses inasmuch as no recognizable lead has been found that will, structurally, guide from one mass to another. Experience, acquired from extensive prospecting in the days of the Catalan forge, shows a great number of widely scattered openings; these openings were made, indiscriminately, on any outcrop of iron ore; the forge was the only test known. Of these many prospects only two deposits of economic size are known. One, the Lake Sanford deposit, has from 70 to 100,000,000 tons in a single mass; the estimates are based on exploration by means of open cuts, diamond drilling and dip needle surveys. In addition the Calamity and Mill Pond deposits contain, by estimate, 40,000,000 tons. Still farther, the Iron Mountain deposit is estimated to contain as much ore as the Sanford deposit. This deposit has been explored to some extent by means of diamond drilling. The total volume of these ores may thus be as great as 250,000,000 tons. Dozens of other test pits in the gabbro area were opened; these showed deposits too small to work.

The structure of the rocks and ores is massive or slightly foliated by pressure and shearing. The shear or foliation planes are, however, no structural guide leading from one deposit to another; these shear planes are local and are neither constant nor areally uniform.

The characteristics of the "straight magnetites" are the exact opposites of the above. The rocks are uniformly of gneissic structure. This structure is not local, but is coextensive with the gneisses. There is great and universal regularity in dip, strike and pitch of these rocks, as indicated by foliation. The gneisses are not uniform in mineral composition. They vary from dark, almost black, to light gray. This variation in color is due to the dominance of dark minerals, such as biotite and hornblende, the light gray, to the absence of these minerals. In addition there are other differences. In the dark gneisses, free magnetite is almost wholly absent. These dark gneisses the writer called "The Oxford Type." They are

feldspathic hornblende, the two minerals arranged in foliation planes of jagged outline. Mr. W. L. Cummings very graphically referred to them as "rag carpet gneisses," a fitting, if somewhat homely description. They contain, as a rule, no free quartz. Within the writer's experience, no iron ore body has ever been found in the dark gneisses.

The gray gneisses, on the other hand, are usually

Fig. 2—Shrinkage stope mining operations in mine of Chateaugay Ore & Iron Company, Lyon Mountain, N. Y. The ore body is 30 feet or more thick.

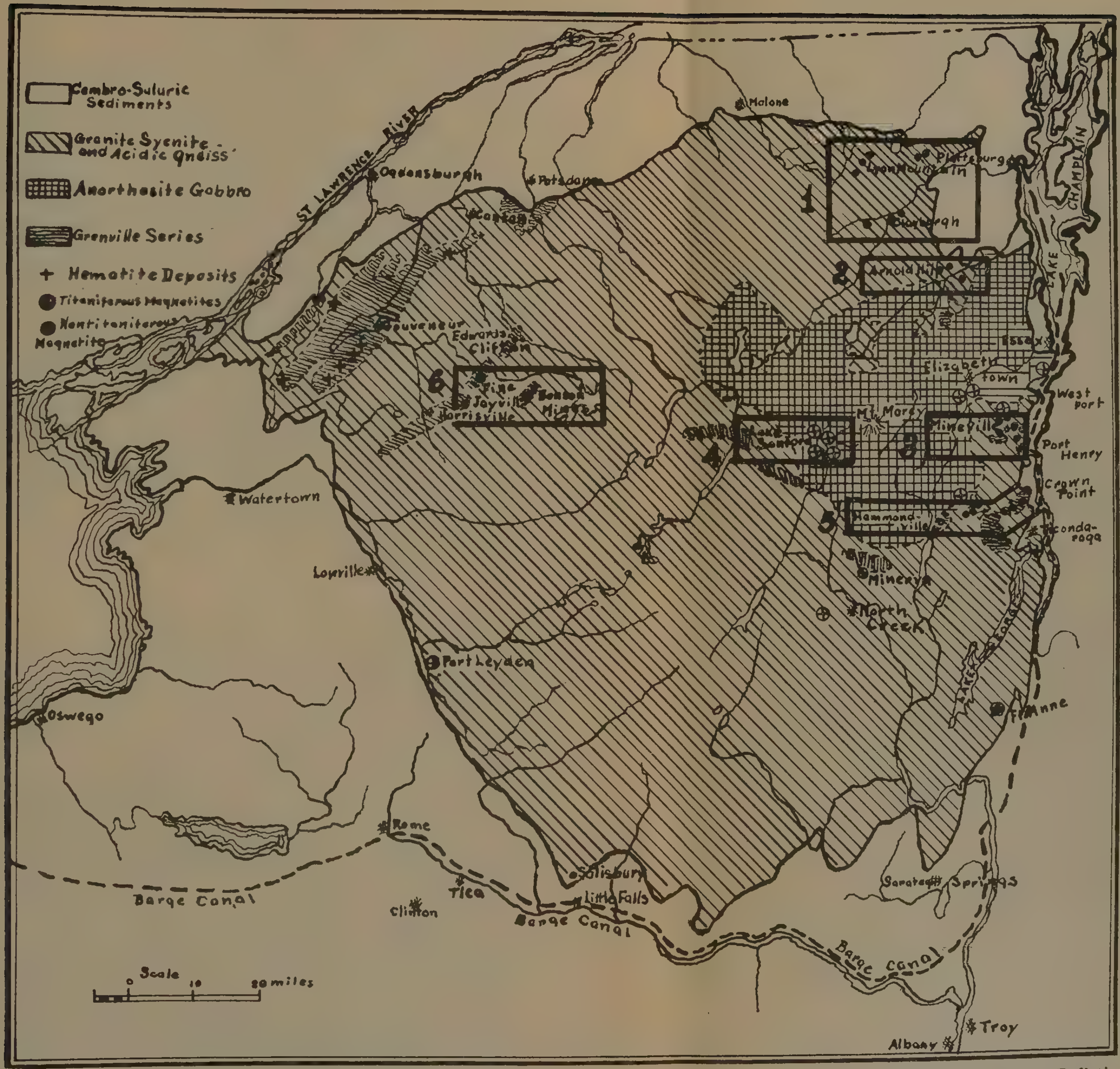
wholly free from hornblende and biotite, the dark mineral is usually magnetite in quantity from 2.9 to 20 per cent. The magnetite occurs in perfect octahedrons and in irregular grains. Quartz, in this rock, is in rounded grains, in many instances the quartz grains are in such proportion as to class them as typical quartzites. In one instance, a graphitic quartzite of the above description passed directly, by the elimination of graphite and the addition of feldspar and magnetite, into typical gray gneiss.

Foliation is faint except when intensified by lines of magnetite or hornblende or biotite, or both, when these are present. Farther, and of great economic importance, also within the writer's experience, all of the major as well as the minor magnetic iron ore deposits are associated with this rock. Of great economic importance, as a guide in prospecting and development, is the fact of the perfect conformity of the ore bodies with the foliation of the gray gneisses. This conformity manifests itself in dip, pitch and strike. When these lines are warped the ore body is warped, if broken by faulting, the ore body is broken as well. Consequently, the limiting lines of exploration of a given outcrop, or advance development work of an operating mine, are plainly indicated.

Areal Extent of the Gabbros and the Gray Gneiss Series

In the New York State Museum Bulletin, No. 119, Messrs. Kemp and Newland publish a map of the areal distribution of the principal rock formations of the Adirondacks and of the iron ore mines. It may be remarked in passing that the trend of pure geology today is to regard not only the gabbros, but the gray gneisses as well, as of eruptive origin. The writer's experience leads him to dissent from this broad conclusion. About the white limestones, there can hardly be two opinions. In all probability they are of sedimentary origin. The white limestone series contain no less than seven straight magnetic ore deposits of great size. In one instance in the writer's experience, gray gneiss, carrying a mined ore body, has been proved to have white limestone above and below the gray gneiss and conformable to it. This indicates that the gray gneisses are of sedimentary origin and are members of the Grenville Series.

The writer is thus strongly inclined to the opinion that



Map showing the areal distribution of the principal rock formations of the Adirondacks and of the iron mining areas (reproduced from Bulletin 119, New York State Museum). Area 1—Lyon Mountain and Saranac. Area 2—Arnold Hill. Area 3—Mineville-Port Henry. Area 4—Lake Sanford. Area 5—Hammondville-Crown Point. Area 6—Benson Mines. Areas enclosed bear no relation to extent or volume of ore deposits. Barge Canal, Plattsburg—Buffalo, shown by dotted line.

Fig. 3—Sintering plant, capacity 450 tons concentrates daily, Chateaugay Ore & Iron Company, Lyon Mountain, N. Y.

Fig. 4—Another view of sintering plant, showing de-dusting fans.

the Grenville and the gray gneisses, together with the contained magnetite ore bodies, are a single geologic unit. This conclusion, however, does not necessarily imply that the contained ore bodies are also sedimentary (contemporaneous). The contained ore may be secondary;—a vein deposit.

The possible economic importance of this view lies in the following:

The Adirondack area proper covers about 10,000 square miles. The intrusive gabbros cover about 1,050 square miles.

If the Grenville includes the gray gneisses, the area covered by this formation is 8,950 square miles. In the recognized Grenville there are seven known mining areas of importance. In every instance the ores outcrop. The question is this: is there any reason for concluding that the iron ores of the Adirondacks are limited by known and more or less developed outcrops? May there not be "blind" deposits which make no surface showing?

To prospect for hidden deposits by blindly "pitting" or drilling would be the height of folly. If the rocks are eruptive, their irregularity closes the door to all except known deposits. If the iron ore series is Grenville, thus sedimentary, structural features, briefly pointed out, will slowly and surely lead to concealed deposits if they exist, and there are no reasons against this expectation. With this factor clearly understood, no forecast of the possible ultimate tonnages can be even guessed. In case of the sedimentary origin of gray gneiss and ores, is there any reason to suppose that every deposit formed has a surface outcrop?

In case of igneous origin of the gray gneisses and ore bodies developed by magmatic segregation, are the exposed ore bodies the only ones developed?

In the former case, structural lines will limit areas of search within the given rock area as a whole; in the latter, the area as a whole is the limit, there are no eliminating lines.

Fig. 5—Blast furnace of Chateaugay Ore & Iron Company, under construction at Standish, N. Y. Capacity 250 tons of special low-phosphorus pig iron daily.

Fig. 6—Another view of blast furnace under construction at Standish, N. Y.

Volume of Ores in the Adirondacks

The suggestions in the preceding topic may seem so visionary as to discredit Mr. Witherbee's estimate of 1,100,000,000 tons. The following will set forth what is actually known in developed areas of active mines and prospective tonnages, based on structural lines, which are immediately adjacent to more or less developed mines:

District	Known Tonnage	Prospective Tonnage	Total Tonnage
Crown Point	3,000,000	10,000,000	13,000,000
Mineville	32,000,000	300,000,000	332,000,000
Lyon Mountain and Saranac	50,000,000	700,000,000	750,000,000
Ausable	25,000,000	300,000,000	325,000,000
Benson	6,000,000	60,000,000	66,000,000
Sanford	70,000,000	180,000,000	250,000,000
Totals	186,000,000	1,550,000,000	1,736,000,000

The foundations for the tons of ore practically in sight, are, first of all, working faces; second, diamond drill holes put down in advance of working faces. This is graphically shown in a longitudinal and transverse section of Witherbee, Sherman & Company's Harmony and Lower Old Bed Mines at Mineville. In these mines, diamond drill holes have been put down 1,000 feet, more or less, in advance of working faces. These diamond drill holes show that within this distance the ore bodies suffer no decrease in thickness, width and per cent. of iron content from the operating faces.

The Cross Section, east to west, of one mine shows the horizontal width of working face to be 2,000 feet, and two diamond drill holes a probable additional width of 2,000 feet, a total of 4,000 feet.

Still another operating mine shows an outcrop of 4,000 feet with a horizontal width, shown by diamond drill holes, of 3,000 feet. At another point a diamond drill hole 2,500 feet in advance of the outcrop shows ore of the same dimensions and grade as the outcrop.

The line of outcrops can be traced by old workings for at least 30,000 feet. Keeping within known limits, that is

limits proved by working faces and diamond drill holes, there is clearly indicated, in the Mineville area alone, a horizontal area of 720,000,000 cubic feet of ore. A continuation of this zone, not so well proved, there are reasons for estimating at 288,000,000 cubic feet additional, a total of 1,008,000,000 cubic feet. Men of wide experience in operating magnetic iron ore mines have stated they have never yet seen one of these mines "bottomed," that is, exhausted. Of course, such mines must have an end, but in the light of experience, who can fix the limit?

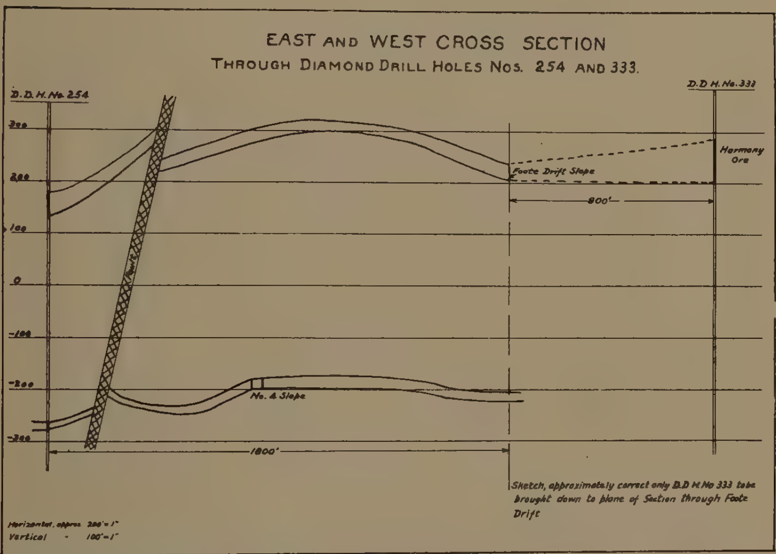


Fig. 7—Vertical east and west cross section through the mines as shown in Fig. 8. The known and worked ore body is 1,800 feet wide; the extension between Foote Drift and diamond drill hole No. 333 is 800 feet. The ore body is probably at least 4,000 feet wide, since drill holes Nos. 254 and 333 each show average thickness of ore at these extremes.

The writer has no illusions whatever as to the probable attitude of mind of many who will read this paper. The only reply to their doubt that can be made is this: The mines of Witherbee, Sherman & Company, of the Port Henry Iron Ore Company, The Chateaugay Ore and Iron Company, The Benson Iron Mines Company and The Sanford Lake Company, have been open to inspection

by properly accredited visitors. A careful inspection of these mines will, in all probability, reveal a solid background of the "visions." In addition, in the Mineville

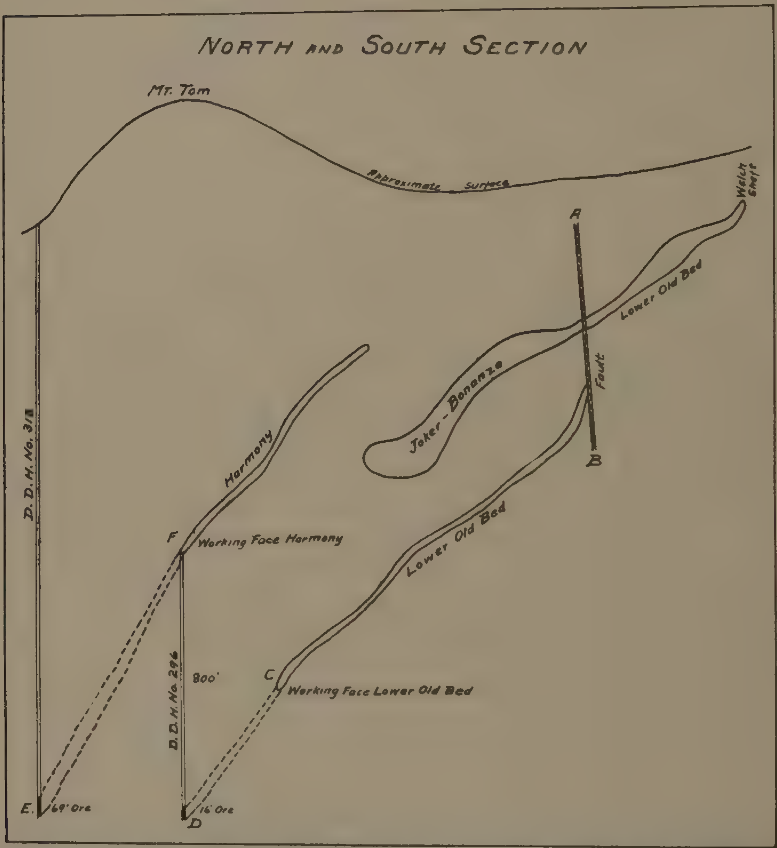


Fig. 8—North and south section through Witherbee, Sherman & Company's mines at Mineville, N. Y. Note the three superimposed ore bodies, Harmony, Joker-Bonanza and Lower Old Bed. Note, on fault line A-B, that Lower Old Bed has been dropped down towards B. Dotted lines show ore bodies proved by diamond drill holes in advance of working faces of the respective mines.

Section, there are at least ten groups of old mines, not now in operation, which have produced considerable tonnages; fifteen in the Ausable Section; four in the Benson mine section; about six in the Saranac and six in the Lyon Mountain section, one of which is in operation. A careful

inspection of these outcrops will discover two striking facts, each supported by the history of iron mining in the Adirondacks. First, in the early days of the iron industry, only rich ores, 50 per cent. iron or more, could be used; these were very limited. Second, in these deposits the mining of the rich ore showed many times the volume of lean ores, ranging from 25 per cent. or even up to 45 per cent. These lean ores, formerly passed by iron miners as impossible, today form the back bone of Adirondack iron ore production, as they undoubtedly will in the future. To anticipate, the Adirondack iron ores possess a characteristic which no other iron ores possess; —they are chemically pure; even the leanest can be raised by magnetic concentration to as high as the theoretical limit of iron in the mineral, 72.4 per cent.

Quoting from Mr. Witherbee's paper, "about 36 years ago (42 years from the present date) when magnetite iron ore was about 35 per cent. of the total iron ore production of the United States, the Adirondack region produced 66 per cent. of this total (23.1 per cent.). The remaining 34 per cent. (11.9 per cent.) was produced by southern New York, New Jersey and Pennsylvania. Two Adirondack mining districts produce today (1916) from 1,250,000 to 1,500,000 tons of shipping ore yearly. The total iron production in the United States in 1916 will be approximately 80,000,000 tons."

The 1,500,000 tons is thus approximately 2 per cent. of the total.

Effect of Intrusive Rocks on the Adirondack Iron Ore Deposits

As has already been stated, gabbro and its metamorphic derivatives are the only exactly recognized intrusives in the Adirondack region, except, of course, the later trap dikes. In the ore bodies at Mineville the gabbro often breaks a given ore body, but the broken off part is readily picked up. There are often heavy rolls,

especially in the foot-wall, evidently caused by lacolith like swellings of the intrusive sheets. Strangely enough, however, this intrusive does not seem to displace the ore bodies except locally by rolls and minor faults. The general structural features, dip, strike and pitch, are only slightly affected, if at all.

So far, within the writer's rather extensive experience, and rather to his surprise, no unlimited mass of gabbro has been encountered in diamond drilling. Apparent sheets (sills) have been repeatedly pierced by diamond drill holes and the practically undisturbed ore bodies and their characteristic rocks have been picked up below. One drill hole, after passing through about 1,800 feet of alternating gray gneiss, typical gabbro and gabbro derivatives, cut 69 feet of ore in the characteristic gray gneiss. The hole was drilled to a depth of 3,006 feet. The last 1,200 feet showed the same alternating rocks as did the upper 1,800 feet.

The writer's inference is that the basal mass of the gabbro lies below the entire iron ore series, which is at least 2,500 feet thick, and that from this basal mass bosses and sills have been interpolated between the beds of gray gneiss, white limestones and the ore bodies themselves.

Summary

The essential features of the foregoing may be briefly summed up as follows:—

(1). There are two distinct types of magnetic iron ores in the Adirondack area; titaniferous and non-titaniferous.

(2). The titaniferous iron ores contain titanium in the form of ilmenite up to 17 per cent. or even more. They are found exclusively in an eruptive gabbro. They are masses segregated from the gabbro. Out of dozens of prospects, only the Sanford Lake deposits are of sufficient volume to warrant attempts to utilize them. Milling tests show that these ores can be milled to concentrates carry-

ing 3 per cent. titanium and iron up to 64 per cent. with phosphorus 0.004 per cent. Successful milling, in the elimination of titanium, however, depends wholly on the physical structure of the ore. Coarse, granular ores yield in milling a high iron product with 0.5 to 3 per cent. of titanium. Dense, fine grained ores, in milling, may eliminate only the non-magnetic gangue. In ores of this latter class the mineral is a mechanical mixture of fine grains of the minerals ilmenite and magnetite or crystalline

Fig. 9—Electric shovel at work underground, Harmony Mine, Witherbee, Sherman & Company, Mineville, N. Y.

intergrowth. They cannot, in this case, be broken apart even at 100 mesh.

(3). The straight or non-titaniferous magnetite ores occur in well foliated gneisses. The ore bodies do not occur in isolated masses, but in extensive sheet-like forms.

These sheet like ore bodies are strictly conformable to the foliation of the gneisses. Their dip, pitch and strike are coincident with that of the gneisses. This feature not only lessens the hazards of prospecting, but is a reliable

guide in determining ore reserves in advance of immediate requirements. As will be seen by consulting the separation tests given below under "Milling Adirondack Iron Ores," the structure of even the leanest ore experimented with (Sample No. 9) is granular and friable, magnetite and gangue existing in independent, loosely coherent grains. The low iron content in the tailings and the high iron content in the heads as shown in samples

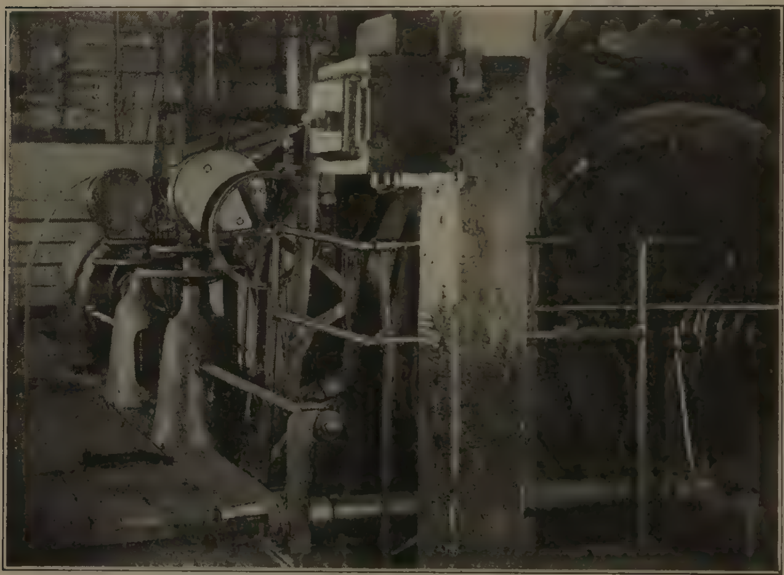


Fig. 10—Underground slope hoist, Harmony Mine, Witherbee, Sherman & Company, Mineville, N. Y.

Nos. 1 to 8 demonstrate this assertion. Magnetite, chemically pure, contains 72.4 per cent. metallic iron. By consulting Samples No. 1 to 7, inclusive, it will be noted that the iron in the concentrate, average of all meshes, is respectively 69.27, 68.82, 69.44, 69.50, 70.00 and 69.75 per cent. These samples demonstrate conclusively three very important facts:—First, the Adirondack straight magnetites are chemically pure. Second, the grains of magnetite and gangue, even phosphorus, are mechanical mixtures. Third, it is only a question of the degree of

crushing in order to get a concentrate with the theoretical limit of metallic iron. Mechanically, this is possible with no other iron ore. It is likely that these ores crushed to 200 mesh would yield 72.4 per cent. iron, the chemical limit; concentration to 70 per cent. grade, is common.

There are approximately 9,000 square miles of the iron ore bearing gray gneisses in the Adirondacks. In this field the area covered by the seven more or less operated districts totals about 250 square miles, approximately 3 per cent. In this 3 per cent. of the total area all known ore bodies outcrop. Whether the 8,750 remaining square miles contain "blind" deposits is not, of course, known. It is likely that they exist. Direct search would be too hazardous to consider. The only safe way is to study structural features of operating mines. This study will likely reveal leads which may be followed with much less risk.

Long before the 186,000,000 tons of assured ore is exhausted, this question will probably be answered.

Milling Adirondack Iron Ores

Previous to 1900, probably 90 per cent. of the iron ores mined in the Adirondacks was shipped as mined or with hand sorting. The grade in iron varied from 50 per cent. to a little over 60 per cent. Up to the year 1880, when Catalan forges were permanently abandoned, ore of 40 to 45 per cent. was often mined and jigged to 55 or 60 per cent. Usually the ores were calcined to facilitate crushing. This process must have been very wasteful since tailing piles near old separators show iron as high as 40 per cent.

In 1910, Witherbee, Sherman & Company, of Mineville, N. Y., mined 581,822 tons of crude ore. Of this, 121,590 tons, about 21 per cent., was shipped as mined. The remaining 79 per cent., 460,232 tons, was magnetically concentrated. The concentrates ran from 61 to 65 per cent. iron. The ratio of concentration was approximately

Fig. 11—Harmony mill, 2,000 tons daily capacity, Harmony "A" shaft, warehouse, shops, etc., Witherbee, Sherman & Company, Mineville, N. Y.

Fig. 12—New Bed mill, capacity 1,500 tons crude ore daily, Witherbee, Sherman & Company, Mineville, N. Y

1.3 to 1, the net crude units of iron per ton was approximately 47 per cent. iron. With recovery at 90 per cent. the total crude iron was about 52 per cent. The Chateaugay Ore and Iron Company have a present mine capacity of upwards of 1,500 tons of crude ore daily, a mill capacity of at least 1,500 tons crude ore, or about 675 tons concentrates.

By referring to Samples Nos. 10, 96-1, 97-2, 98-3, 100-5 and 102-7, in the following tables, it will be noted that the finest mesh was through 16. This was the finest mesh tried. The reasons for this limitation were: first, that the ores experimented with were "special low phosphorus"; second, the experiments indicated that at the 16 mesh the magnetite and gangue were practically broken apart; the recovery of the total iron units was practically 92 per cent. in concentrates with iron 61 to 69 per cent.

Taking a single example, No. 96-1, as practically representative of the six samples, the problem will work out as follows:

75 units crude ore, iron content 29.36 per cent.
30 units concentrates iron content, 67.85 per cent.
75 x 29.36=2,202, total iron units in crude ore,
30 x 67.85=2,035.5, total units recovered in concentrates,
2,035.5÷2,202=92 per cent. of total iron recovered,
29.36 x 92=27, net iron units in the crude ore.

With mining costs estimated at approximately $1.25 per ton and milling per ton of crude ore approximately 35 cents, the cost of the 27 net iron units is thus about 160 cents ÷ 27 = 5.9 cents per unit. This cost will include taxes, insurance, etc., but not administration expenses. It is thus evident that the unit must sell for not less than 8 cents, f. o. b. point of origin, in order to incur profitable operations.

According to M. A. Hanna & Co.'s "Lake Superior Iron Ores, 1922," Old Range bessemer ore, 55 per cent. iron, 0.045 per cent. phosphorus sold at Lake Erie Ports at $0.12818 per unit.

By comparison, it would appear that so far as per-

centage of iron is concerned, Adirondack concentrates are 23 per cent. higher in iron and 93.4 per cent. lower in phosphorus.

As an example of the results which may be expected in milling a crude ore of even a lower iron content, the following is submitted. Sample No. 4 in the accompanying tables shows 24.72 per cent. iron in the crude ore. Working this out as before in Sample No. 96-1, we have:—

975.6 x 24.72=24,116.83, total iron units.
329.9 x 69.5 =22,928.05, total iron units recovered.
22,928.05÷24,116.83=95 per cent. recovery.
Net iron units in the crude, 24.72 x 95=23.48.

With the same accrued costs for mining and milling, the cost per unit of iron is 160 cents÷23.48=6.81 cents.

There is, however, to be considered in Sample No. 4 that 239.9 grams of the 329.9 grams of concentrates, practically 73 per cent. will pass 60 mesh.

This means a finer product than furnaces can use on account of "blowing over" and "banking blast." To obviate this, sintering is resorted to at a cost of about $1.50 for 63 iron units, about 2.4 cents per unit. This, added to mining and milling, reaches a total of 9.21 cents per unit for the sintered product. That is 17.14 units out of the 23.48 net units will cost approximately 2.4 cents each for sintering. The average cost per unit of iron will then be

17.14 units x 9.21 cents=	157.85 cents
6.34 units x 6.81 cents=	42.17 cents
23.48	200.03 cents

The average cost per unit, including sintering, will be 8.52 cents. Comparing the above costs with the selling price of Old Range bessemer ore, 55 per cent. iron @ $0.12818 per unit, Sample No. 4 concentrates have 26 per cent. more iron and approximately 50 per cent. less phosphorus. This means that the per unit cost of Adirondack sintered concentrates with 63 per cent. iron is only 66.4 per cent. of the selling price of 55 per cent. Old Range bessemer ores at Lake Erie Ports. Unit for unit or ton

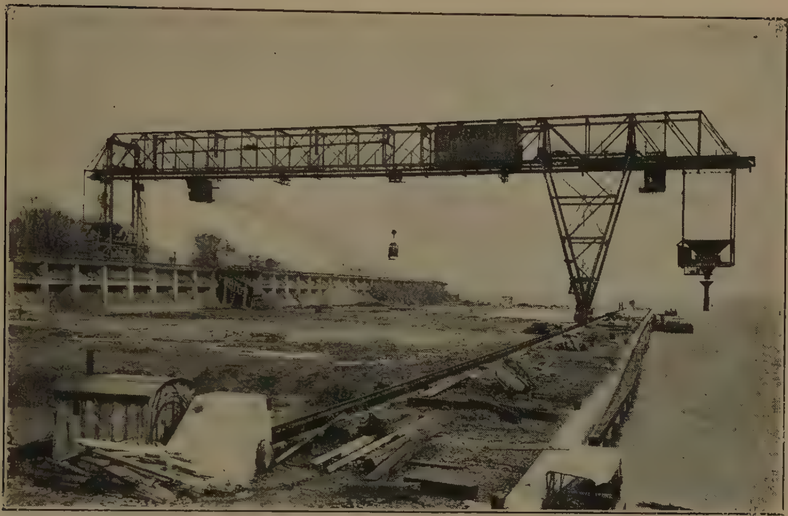


Fig. 13—New ore storage and shipping wharf of Lake Champlain and Moriah Railroad Company at Port Henry, N. Y., 900 feet long by 250 feet wide, showing facilities for shipment by water.

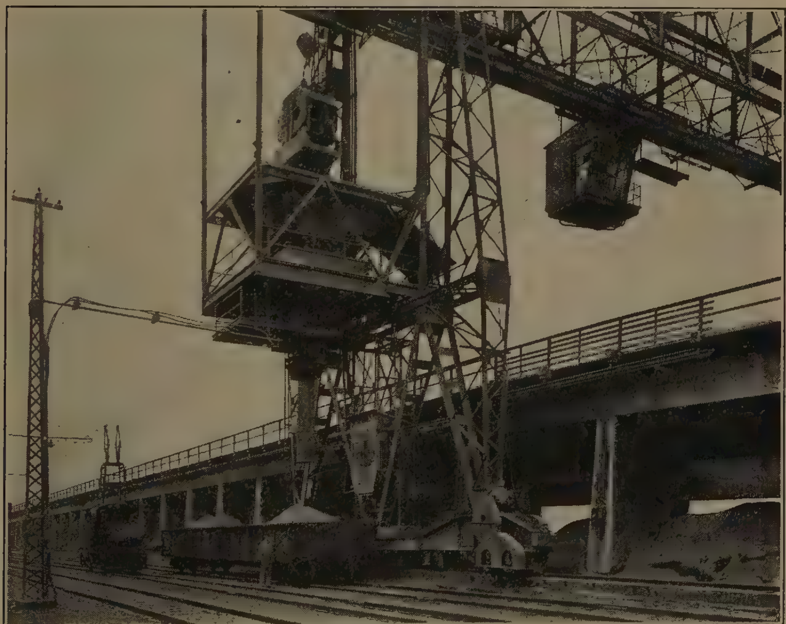


Fig. 14—New wharf of Lake Champlain and Moriah Railroad Company at Port Henry, showing concrete trestle and method of loading cars.

for ton, if the Adirondack concentrates sold at the price of \$0.12818 per unit there would be (12.818—8.52=4.298) 4.298 cents per unit which would represent net over cost. On this basis, which seems to be a fair one, the Adirondack concentrates would be a formidable competitor of Lake ores. With this equation of prices the concentrate tonnage of the Adirondack ores would be more than doubled and the supply of raw material is abundant to furnish this output for years.

Mr. Witherbee, in the paper quoted, says:—"The Adirondack field promises, on present showing as above, when developed, to produce 5,000,000 tons of concentrates annually for over 100 years." In the writer's opinion, this estimate is conservative.

Still Lower-Grade Crude Ores

There is apparently, in the Mineville, Ausable and Lyon Mountain Districts, an unestimated tonnage of ore or rock carrying not less than 15 per cent. iron. This can be quarried and delivered to a mill at a cost not to exceed 50 cents a ton. As before, with milling costs at 35 cents, the total cost per ton, crude, would be 85 cents.

Sample No. 9 was taken from a ledge of this material. The crude ran 15.25 per cent. iron; the concentrates 63.85 per cent. iron. The concentration ratio was 6.15 to 1, recovery was 68.05 per cent. The mesh, through 4 on 8, gave heads 52.1 per cent. iron; through 8 on 16, 59.7 per cent. iron; through 16, 66.43 per cent. iron: tails, 5.84 per cent. iron.

Finer crushing is plainly indicated. As it stands, the results are as follows:—Net units, 15.25x68.05=10.38 units recovered at a cost of 85÷10.38=8.2 cents per unit.

In spite of the above favorable showing, it is likely on such low-grade ore that the cost for milling would be much more than 35 cents per ton. In any event a very large quarrying and milling plant would be required were there to be any prospect of success. As a matter of fact,

an ore of this grade need not be considered for very many years. It is, however, an ultimate reserve not to be lost sight of.

In presenting the following tables of the results of magnetic separation tests covering Samples Nos. 1 to 8 inclusive, these were a few of the very many tests made by the writer personally. The samples in no case exceeded 1,000 grams. The experiments were "laboratory." The question will immediately arise: What approximation to these results can be had on a commercial scale? The answer is simple: They can be exactly reproduced. As pointed out under sample No. 11 in the following tables, the tailings were not crushed fine enough to allow a separation of magnetite and gangue. The result was a failure of the operating company on account of a loss of 39.4 per cent. of the crude iron units in the tailings. Under sample No. 12, the loss in tailings was 14.3 per cent. of the total iron in the original ore. The experiment shows that, without further crushing, 66.66 per cent. of the total iron was recovered in heads with 63.26 per cent. iron; of

Fig. 15—Blast furnace of Witherbee, Sherman & Company at Port Henry, N. Y.

the total iron below 20 mesh, 90.00 per cent. was recovered.

There is only one of two conclusions possible (or both), either the separating machines were over-crowded or there was gross negligence on the part of the operators.

As a specific example, to the writer's personal knowledge, a given mill was producing 63 to 65 per cent. concentrates with an average of 0.014 per cent. phosphorus. A call was made for 0.010 per cent. phosphorus. The call was met by a simple expedient. Between the finishing machines of the mill and the storage bin for concentrates, a single magnetic machine was interpolated. The product of the interpolated machine was 68 per cent. iron with phosphorus 0.010 per cent. or even lower.

This is a well known fundamental in magnetic milling practice. The depth of ore on the belt or pulley should be 1 grain whether the grain is .1″ or .01″ in diameter. With two, three, or ten grain depth, the capacity of a given machine is two, three, or ten times that of one grain depth. This multiplied capacity unavoidably entails two undesirable consequences: a diluted concentrate and a higher loss of iron in the tailings.

Along the lines of laboratory experiments, as illustrated in the following tables, ores as low as 24 per cent. iron are successfully milled. The recovery of total iron units, in this case, is generally about 85 per cent.: the concentrates contain 61 to 65 per cent. iron. In ores of 47 to 50 per cent. iron, 96 per cent. is recovered, with an iron content in the concentrates of 61 to 63 per cent.

In Witherbee, Sherman & Company's mills about 15 per cent. of the concentrates pass 60 mesh. The actual, every day recovery of milling plants operating on Adirondack crude ore on a large scale, 1,000 to 1,500 tons concentrates, is 85 to 96 per cent. recovery, 3 to 6 per cent. iron in the tails, grade of crude ore, 24 to 50 per cent. iron.

This is a specific answer to the query, "Can laboratory results be reproduced commercially?" It is being done.

One point of comparison between Lake ores and Adirondack concentrates, I have never heard mentioned: the comparative unit cost of iron in freight charges. A 51.5 per cent. iron, non-bessemer Lake ore has 18.5 per cent. less iron than an Adirondack ore of 61 per cent. In the Adirondack ore of 61 per cent. there is 84.2 per cent. magnetite and 15.7 per cent. gangue. The Lake ore of 51.5 per cent. iron (hematite) has 73.5 per cent. hematite (Fe_2O_3) and 26.5 per cent. gangue. The rail freight per ton mile is assumed to be 1 cent or $1.00 per hundred miles. The 100 mile rate per unit of iron on Lake hematite is thus 1.36 cents; a similar condition with Adirondack concentrates, as magnetite (Fe_3O_4), would be 1.189 cents per unit of iron. That is, the freight per unit of iron of Adirondack concentrates is only 87.4 per cent. of that of 51.5 per cent. Lake ores.

On a freight charge basis alone, there is a neutral point between Buffalo and New York City where competition between non-bessemer Lake ores and Adirondack concentrates would apparently meet on even terms. But this is to be thrown into the scale for adjustment. By price quotations 51.5 per cent. non-bessemer Lake ores are quoted in the "Engineering and Mining Journal" at Lake Ports at 11.07 cents a unit as against Mineville 63 per cent. concentrates, f. o. b. Port Henry, at 9.127 cents a unit. This price discrimination has already been referred to.

Probable Reasons for Discrimination in Unit Price

The following statements are out of the writer's province of personal experience. They must, therefore, be submitted tentatively. Summed up briefly, they are: first, early furnace practice; second, relative volume of ore.

To the writer's personal knowledge, magnetic iron ores were charged in blast furnaces practically as they came from the mines. The largest masses of ore were "sledged" to lumps of 100 pounds more or less. Imagine a

one-foot cube of rock salt immersed in water and the time of solution noted. Imagine the one-foot cube crushed into .1″ cubes and immersed in water and the comparative time of solution noted. This homely illustration is yet apt. It illustrates approximately the relative time of reduction and the fuel consumption of 100 pound lumps of dense magnetite and the same magnetite reduced to cubes of .1″ and charged in the same furnace. This is practically the comparison of magnetite shipped less than 40 years ago and the magnetite shipped by magnetic iron ore manufacturers today.

This, I assume, is the basal prejudice of blast furnace men today even against magnetic concentrates. The writer has diligently sought opinions of practical furnace masters. Both sides are positive. One side affirms lower furnace yield and higher fuel cost per magnetite unit; the other side affirms just as positively that there is no difference in either production or fuel cost.

About 1885, as Mr. Witherbee states, magnetite constituted about 35 per cent. of the total iron ore produced in the United States. Today, it is about 3 per cent. In 1916 the production of the Lake Superior Region was 66,658,466 tons. Personally, the writer knows that the general idea which is prevalent is that the Adirondack iron ore field is very limited, and the volume of production irregular and not to be depended upon for any length of time. With this feeling dominant, iron and steel manufacturers naturally turn to a source of supply officially estimated at billions of tons in preference to what is regarded as a limited and irregular source, especially with a prejudice against magnetites.

Whatever the relative value of these facts, they are, nevertheless, facts.

In conclusion, the writer is thoroughly convinced of the following:

First, The iron ore reserves of the Adirondack Region are not less than 1,500,000,000 tons.

Second, That on a basis of a concentration ratio of 2.5 to 1, these reserves will produce not less than 600,000.-000 tons of 61 to 65 per cent. concentrates of bessemer grade in phosphorus of which probably 300,000,000 tons would be "special low phosphorus."

Third, Unit for unit, these concentrates can be marketed on even terms, at some point not far east of Buffalo, with the best of the Lake ores.

Electro-Jigging Magnet Separation Tests

The electro-jigging magnet is, as its name implies, a small electro-magnet with a make and break circuit device operated by hand, the object of the make and break circuit is to shake out the non-magnetic material which is mechanically picked up with the magnetic iron ore even when gangue and ore are completely broken apart. In passing judgment on a more or less developed prospect, this device is most useful. It gives one a working idea of the mesh to which the ore must be crushed in order to break the iron from the gangue; and, most important of all, it determines the mesh at which the major part of the phosphorus (invariably in the form of apatite, a phosphate of lime) will be eliminated. In short, the device will enable one to determine the degree of the amenability of the ore to economic milling. It is a most useful device in testing the every day working of the mill. In many of the following tests the ore was immediately through 40 on 60 mesh (standard screens).

SAMPLE NO. 1.

Mesh of Screen	Product	Weight, Grams	Per Cent. Iron	Per Cent. Phosphorus
40 on 60............	concentrates	76.2	68.93	0.004
	tails.........	70.6	2.04	
		146.8		
60 on 80............	concentrates	97.1	69.13	0.006
	tails........	97.8	2.92	
		194.9		
80 on 100...........	concentrates	43.9	69.50	0.004
	tails........	48.7	2.14	
		92.6		
Total...........	concentrates	342.9	69.27	0.005
Total...........	tails........	362.7	2.30	
	Crude ore...	705.6	34.85	0.050

Per cent. iron recovery, 96 per cent.
Ratio of concentration, 2.08 to 1, by analysis.
Ratio of concentration, 2.05 to 1, by weight.
Ratio of phosphorus to iron in the crude ore, 1 to 697.
Ratio of phosphorus to iron in the concentrates, 1 to 13,854.

SAMPLE NO. 2.

Mesh of Screen	Product	Weight, Grams	Per Cent. Iron	Per Cent. Phosphorus
40 on 60............	concentrates	54.6	68.17	0.022
	tails........	56.6	2.24	
		111.2		
60 on 80............	concentrates	78.2	68.36	0.014
	tails	85.0	1.95	
		163.2		
80 on 100...........	concentrates	34.0	69.40	0.014
	tails........	39.0	1.95	
		73.0		
Through 100........	concentrates	109.2	69.30	0.013
	tails........	147.3	2.53	
		256.5		
Total...........	concentrates	276.0	68.82	0.014
Total...........	tails........	327.9	2.26	
	Crude ore...	603.9	32.68	0.318

Recovered as concentrates 45.7 per cent of weight; tails 54.3 per cent.
Per cent. of iron recovery, 95 per cent.
Ratio of concentration, 2.22 to 1 by analysis.
Ratio of concentration, 2.35 to 1 by weight.
Ratio of phosphorus to iron in the crude ore, 1 to 103.
Ratio of phosphorus to iron in the concentrates, 1 to 4,916

SAMPLE NO. 3.

Mesh of Screen	Product	Weight, Grams	Per Cent. Iron	Per Cent. Phosphorus
40 on 60............	concentrates	78.1	69.12	0 013
	tails........	98.6	1.95	
		176.7		
60 on 80............	concentrates	89.0	69.12	0.010
	tails........	119.9	1.46	
		208.9		
80 on 100...........	concentrates	36.4	69.88	0.013
	tails........	58.0	1.65	
		94.4		
Though 100........	concentrates	118.2	69.78	0.013
	tails........	198.8	1.48	
		317.0		
Total...........	concentrates	321.7	69.44	0.013
Total...........	tails........	475.3	1.58	
	Crude ore...	797.0	28.98	0.211

Per cent. of iron recovery, 96 per cent.
Ratio of concentration, 2.5 to 1 by analysis.
Ratio of concentration, 2.48 to 1 by weight.
Ratio of phosphorus to iron in the crude ore, 1 to 137.
Ratio of phosphorus to iron in the concentrates, 1 to 5,341.

SAMPLE NO. 4.

Mesh of Screen	Product	Weight, Grams	Per Cent. Iron	Per Cent. Phosphorus
40 on 60	concentrates	90.0	69.22	0.006
	tails	150.0	1.55	
		240.0		
60 on 80	concentrates	95.3	69.60	0.006
	tails	182.9	1.55	
		278.2		
80 on 100	concentrates	33.8	69.50	0.005
	tails	71.2	1.65	
		105.0		
Through 100	concentrates	110.8	69.50	0.007
	tails	241.6	2.34	
		352.4		
Total	concentrates	329.9	69.50	0.006
Total	tails	645.7	1.85	
	Crude ore	975.6	24.72	0.010

Recovered as concentrates 33.81 per cent of weight; tails 66.19 per cent.
Per cent. of iron recovery, 95 per cent.
Ratio of concentration, 2.94 to 1 by analysis.
Ratio of concentration, 2.95 to 1 by weight.
Ratio of phosphorus to iron in the crude ore, 1 to 2,472.
Ratio of phosphorus to iron in the concentrates, 1 to 11,583.

SAMPLE NO. 5

Mesh of Screen	Product	Weight, Grams	Per Cent. Iron	Per Cent. Phosphorus
40 on 60	concentrates	55.0	69.88	0.002
	tails	47.8	2.24	
		102.8		
60 on 80	concentrates	85.0	70.07	0.004
	tails	79.8	2.14	
		164.8		
80 on 100	concentrates	46.9	70.17	0.003
	tails	49.2		
		96.1		
Through 100	concentrates	134.0	70.07	0.003
	tails	154.9		
		288.9		
Total	concentrates	320.9	70.00	0.003
Total	tails	331.7	2.15	
	Crude ore	652.6	35.55	0.021

Recovered as concentrates 49.17 per cent of weight; tails 50.83 per cent.
Per cent. of iron recovery, 96 per cent.
Ratio of concentration, 1.1 to 1 by analysis.
Ratio of concentration, 2 to 1 by weight.
Ratio of phosphorus to iron in the crude ore, 1 to 1,693.
Ratio of phosphorus to iron in the concentrates, 1 to 23,333.

SAMPLE NO. 6

Mesh of Screen	Product	Weight, Grams	Per Cent. Iron	Per Cent. Phosphorus
40 on 60	concentrates	81.0	69.12	0.009
	tails	84.9	2.04	
		165.9		
60 on 80	concentrates	89.4	69.98	0.006
	tails	103.0	1.46	
		192.4		
80 on 100	concentrates	39.5	70.07	0.004
	tails	49.6	1.85	
		89.1		
Through 100	concentrates	127.0	69.88	0.004
	tails	152.8	2.14	
		279.8		
Total	concentrates	336.9	69.74	0.005
Total	tails	390.3	1.90	
	Crude ore	727.2	33.35	

Recovered as concentrates 45.33 per cent of weight; tails 54.67 per cent.
Per cent. of iron recovery, 97 per cent.
Ratio of concentration, 2.09 to 1 by analysis.
Ratio of concentration, 2.15 to 1 by weight.
Ratio of phosphorus to iron in the concentrates, 1 to 13.948.

SAMPLE NO. 7

Mesh of Screen	Product	Weight, Grams	Per Cent. Iron	Per Cent. Phosphorus
40 on 60	concentrates	70.3	69.50	0.005
	tails	59.5	2.72	
		129.8		
60 on 80	concentrates	86.3	69.90	0.009
	tails	79.7	2.24	
		166.0		
80 on 100	concentrates	38.6	69.70	0.010
	tails	37.7	2.44	
		76.3		
Through 100	concentrates	126.3	69.90	0.023
	tails	121.7	3.02	
		248.0		
Total	concentrates	321.5	69.75	0.009
Total	tails	298.6	2.68	
	Crude ore	620.1	37.45	0.061

Recovered as concentrates 51.84 per cent; tails 48.16 per cent.
Per cent. of iron recovery, 96 per cent.
Ratio of concentration, 1.86 to 1 by analysis.
Ratio of concentration, 1.9 to 1 by weight.
Ratio of phosphorus to iron in the crude ore, 1 to 614.
Ratio of phosphorus to iron in the concentrates, 1 to 7,750.

SAMPLE NO. 8

Mesh of Screen	Product	Weight, Grams	Per Cent. Iron	Per Cent. Phosphorus
60 on 80............	concentrates	6.75	69.87	0.004
	tails........	7.00	2.58	0.010
80 on 100...........	concentrates	.50	29.67	0.004
	tails.........	.75	2.87	0.305
Through 100........	concentrates	8.50	67.40	0.002
	tails........	10.25	2.87	0.014
Total...........	heads.......	15.25	68.48	
Total...........	tails........	18.00		
	Crude ore...	33.25	32.90	

Per cent. of iron recovery, 90 per cent.
Ratio of concentration, 2.08 to 1 by analysis.
Ratio of concentration, 2.18 to 1 by weight.
Per cent. iron in crude ore, 32.9.
Per cent. iron in concentrates, 68.48; per cent. phosphorus, 0.003.

SAMPLE NO. 9

General statement of results of magnetic separation.
Mesh varies from .5 inch to .25 inch to through 18 mesh.
Average iron content in crude ore, 15.25 per cent.
Average iron content in concentrates, 63.85 per cent.
Average iron content in tails, 5.84 per cent.
Ratio of concentration, 6.15 to 1.
Per cent. recovery of iron, 68.05 per cent.

SAMPLE NO. 10

Sample crushed to 8 mesh, Standard Screen.
Average iron content in crude ore, 31.25 per cent.
Average phosphorus content in crude ore, 0.025 per cent.
Average iron content in concentrates, 68.44 per cent.
Average phosphorus content in concentrates, 0.009 per cent.
Per cent. recovery of iron, 77 per cent.
Ratio of concentration, 2.15 to 1 by analysis.
Ratio of concentration, 2.8 to 1 by weight.

SAMPLE NO. 11

This sample represents tailings from a magnetic mill operated, it is estimated, under the following conditions:

Crude ore, about 45 per cent. iron, crushed to about 10 mesh. The tailings from the above ran 17.73 per cent. iron. Approximately, therefore, the iron loss in the tailings was 39.4 per cent. or the iron units recovered were 27.27.

The loss was so great the enterprise was abandoned. The loss in tailings was ascribed to the presence of marcite to the extent of 39.4 per cent. of the total iron.

The writer took a 144-pound sample of these tailings, crushed them to through 30 mesh and separated by means of a magnetic separator with the following results: 144 x 17.73=2,553.12 iron units in the crude ore; and 21 x 65.18=1,368.78 iron units recovered as magnetic concentrates. The magnetic units in an assumed non-magnetic ore thus amounted to 53.61 per cent.

With the same mesh and with a higher amperage, 16 heads were recovered magnetically or 46 per cent. of the iron considered non-magnetic. The 16 heads, however, ran only 34.32 per cent. iron. It is evident that finer crushing is plainly indicated. In this event the total magnetic iron recovery from the supposed non-magnetic tailings would have been over 80 per cent. or 2,042.49 iron units out of the original 2,553.12 units.

The above is cited to emphasize the great importance of a careful study of the character of any ore before milling operations on a commercial scale are undertaken.

SAMPLE NO. 12

This sample is taken from another extensive tailings pile. In this sample it is evident that no non-magnetic iron existed. The tailings ran 14.3 per cent. iron. Free magnetite showed in the tailings. They were sampled and iron determined in the various sizes as follows:

Screen	Crude Ore (Tailings) Weight	Per Cent. Iron	Concentrates Weight	Per Cent. Iron
On 20 mesh	390.00	9.5	....	....
On 40 mesh	160.00	10.7	27.2	51.8
On 60 mesh	154.00	16.1	34.2	64.1
On 80 mesh	65.60	18.2	16.3	65.8
On 100 mesh	229.00	22.7	72.8	66.6
Total	998.60	14.3	150.5	63.2

Average per cent. of iron in crude ore, 14.3 per cent.

Average per cent. of iron in concentrates, 63.26 per cent.

Percentage of iron recovered, including 20 mesh, 66.66.

Percentage of iron recovered, excluding 20 mesh, 90.00.

The 20 mesh is excluded from consideration since none of the 3,705.0 units contained therein could be recovered of commercial grade without, as shown in the table, being recrushed to 40 mesh or finer.

The point to be brought out is this: Either by over-crowding the machines or by carelessness in handling the machines, in 1,000 tons of tailings 150.5 tons of 63.26 per cent. iron concentrates were lost. Valuing these concentrates at 8 cents a unit, the money loss was $761.53. This would be about two days mill run; thus about $380.76 a day.

In another Adirondack mill operation free magnetite in the tailings amounted to 13 per cent. or 18 per cent. The tonnage is large; the high iron content of the tailings was due to crowding the machines.

THROUGH 16 MESH OVER BELT MACHINE USING 7¼ AMPERES

	No. 96. Sample No. 1			No. 97. Sample No. 2		
	Crude 75 Pounds	Heads 30 Pounds	Tails 45 Pounds	Crude 87 Pounds	Heads 28 Pounds	Tails 59 Pounds
Total iron	29.36	67.85	....	23.91	66.98	....
Soluble iron	29.36	....	2.45	23.91	....	2.35
Silica	....	3.40	....	....	5.24	....
Alumina	....	2.60	....	....	1.90	....
Lime	....	0.13	....	....	0.21	....
Magnesia	....	0.21	....	....	0.23	....
Phosphorus	0.005	0.006	....	0.003	....	....
Sulphur	....	trace	....	....	trace	....
Manganese	....	0.08	....	....	0.09	....
Titanium	....	0.61	....	....	0.22	....

	No. 98. Sample No. 3			No. 99. Sample No. 4		
	Crude 79 Pounds	Heads 41 Pounds	Tails 38 Pounds	Crude 78 Pounds	Heads 29 Pounds	Tails 49 Pounds
Total iron	38.20	69.28	....	28.77	65.14	....
Soluble iron	38.20	....	2.97	28.77	....	5.83
Silica	....	2.55	....	....	6.65	....
Alumina	....	1.30	....	....	2.77	....
Lime	....	0.10	....	....	0.18	....
Magnesia	....	0.35	....	....	0.38	....
Phosphorus	0.009	0.006	....	0.020	0.010	....
Sulphur	....	trace	....	....	trace	....
Manganese	....	0.08	....	....	0.05	....
Titanium	....	0.17	....	....	0.33	....

	No. 100. Sample No. 5			No. 101. Sample No. 6		
	Crude 73 Pounds	Heads 35 Pounds	Tails 38 Pounds	Crude 73 Pounds	Heads 37 Pounds	Tails 36 Pounds
Total iron	33.68	62.73	....	36.91	67.90	....
Soluble iron	33.68	....	4.09	36.91	....	2.76
Silica	....	8.75	....	....	3.10	....
Alumina	....	3.90	....	....	0.08	....
Lime	....	0.23	....	....	0.25	....
Magnesia	....	0.56	....	....	....	....
Phosphorus	0.015	0.006	....	0.007	0.003	....
Sulphur	....	trace	....	....	trace	....
Manganese	....	0.05	....	....	0.10	....
Titanium	....	0.28	....	....	0.66	....

	No. 102. Sample No. 7			No. 103. Sample No. 8			No. 104. Sample No. 9		
	Crude 74 Pounds	Heads 35 Pounds	Tails 39 Pounds	Crude 80 Pounds	Heads 30 Pounds	Tails 50 Pounds	Crude 74 Pounds	Heads 54 Pounds	Tails 20 Pounds
Total iron..	35.30	67.74	.....	27.43	65.57	.....	54.86	68.77	.....
Soluble iron.	35.30	.....	2.76	.....	.....	2.35	54.86	.....	8.60
Silica.......	.....	3.10	.....	.....	5.32	.....	.....	2.63	.....
Alumina....	.....	.....	.....	.....	3.38	.....	.....	.....	.....
Lime.......	.....	0.03	.....	.....	0.68	.....	.....	0.16	.....
Magnesia...	.....	0.31	.....	.....	0.49	.....	.....	0.10	.....
Phosphorus.	0.005	0.004	.....	0.015	0.004	.....	0.010	0.008	.....
Sulphur....	.....	trace	.....	.....	nil	.....	.....	nil	.....
Manganese .	.....	0.06	.....	.....	0.08	.....	.....	0.06	.....
Titanium...	.....	0.66	.....	.....	0.61	.....	.....	0.17	.....

Magnetic Separation Test of Sanford Titaniferous Ores

The ore is a hard, dense, titaniferous magnetite, contains from 46 per cent. to 52 per cent. iron, 7 per cent. to 12 per cent. titanium, 0.20 per cent. vanadium and is very low in phosphorus. Complete typical analysis of Sanford ore, together with analysis of concentrates made therefrom, will be found below:

ANALYSES

Analysis	Crude Ore Per Cent.	Concentrates Per Cent.
Silica..............................	5.18	2.26
Iron oxide { FeO..................	32.01	33.19
Iron oxide { Fe_2O_3................	32.24	43.51
Alumina.........................	4.20	4.52
Titanic oxide.....................	21.02	12.34
Manganese oxide (MnO)	.34	.27
Vanadic oxide....................	.35	.47
Chrome oxide (Cr_2O_3)............	.16	.19
Lime............................	.42	.10
Magnesia.........................	1.86	1.48
Alkalies..........................	.54	trace
Phosphoric anhydride.............	.035	.007
Sulphur..........................	.142	.104
Carbonic anhydride...............	.50	.36
Carbonaceous matter..............	.16	.17
Combined water..................	1.41	1.45
	100.567	100.421
Phosphorus......................	.018	.003
Chromium.......................	.112	.134
Vanadium.......................	.200	.260
Manganese......................	.260	.209
Titanium........................	12.61	7.40
Metallic iron.....................	47.47	56.29
Nickel..........................	Possibly a trace—test doubtful.	

Brief Summary of the Foregoing Paper

The salient facts in the body of this paper can be stated as follows:—The total iron ore bearing area of the Adirondack Region is, approximately, 10,000 square miles.

Of this total, there are approximately 1,500 square miles of gabbro and other old intrusive rocks. The iron ores of this area are, so far as known, titaniferous. There are very many old prospects in this area, but, so far as known, the Sanford Lake deposits are the only ones of economic size. These deposits have fairly well proved 70 to 100,000,000 tons of crude ore with a possibility of 180,000,000 tons additional. This ore can be separated to yield concentrates with 56 to 60 per cent. iron, 3 to 7 per cent. titanium and with 0.004 per cent. phosphorus.

The remaining area, 8,500 square miles, are mainly gray gneisses probably of sedimentary origin and, probably, belonging to the Grenville series of white limestones, known sedimentaries. A total area of more or less productive mines, covers about 250 square miles. This area is divided into six distinct sections, the Crown Point, Mineville, Ausable, Saranac, Lyon Mountain, Benson Mines and the Clifton Group.

There are at present three operating companies: Witherbee Sherman & Company, the Port Henry Iron Ore Company (Mineville Section), Chateaugay Ore and Iron Company, Lyon Mountain section. These three companies are equipped to turn out 1,500,000 tons of concentrates yearly with 61 to 68 per cent. iron and from 0.2 to 0.004 per cent. phosphorus. At least 750,000 tons of this output will be 61 to 65 per cent. iron, phosphorus 0.01 to 0.004 per cent. If the market would absorb it, the finished product could be brought, within two years, up to at least 3,000,000 tons.

The crude ore in sight is about 186,000,000 tons, the prospective tonnage is 1,736,000,000 tons, including the Sanford Lake titaniferous iron ores.

The "gray gneiss" ores, non-titaniferous, are, in sight and prospective, 1,500,000,000 tons.

The magnetite in the gray gneiss ore is practically chemically pure. That is it contains the theoretical limit of 72.4 per cent. metallic iron. The crude ores are granular and friable. This makes for high-grade milling since, in crushing, the magnetite and gangue may be broken completely apart. Subjected to the action of magnetic machines, the concentrates are a high-grade product. In present every day practice, crude ores with a total of 25 per cent. iron yield, with 85 per cent. recovery of the crude iron units, concentrates up to 68 per cent. iron with phosphorus 0.01 to 0.004 per cent. Experiments show that from 15 to 30 per cent. crude iron units, crushed to 73 per cent. through 60 mesh, yield concentrates, the average of all meshes, as high as 70 per cent. iron and 0.004 per cent. phosphorus with 92 to 96 per cent. recovery of the total crude iron units. It has been proved experimentally that, crushing through 150 to 200 mesh, 71 to 72 per cent. iron concentrates with phosphorus practically eliminated, and a 96 to 98 per cent. recovery of the crude iron units may be attained.

The 1,500,000,000 tons of non-titaniferous gray gneiss ores will, on the average, have a concentration ratio of 2.4 to 1.63 per cent. iron concentrates. The yield of concentrates on this basis will be 625,000,000 tons. This is equivalent to an annual production of 6,250,000 tons annually for 100 years.

The 116,000,000 tons of gray gneiss ores assured will yield, on the same basis, a total of 48,340,000 tons, equivalent to a production of 1,500,000 tons of concentrates yearly for 32 years. This 1,500,000 tons is approximately the yearly production of fair business years. Compared with the Lake ores of 51.5 to 55 per cent., ton for ton, the Adirondack concentrates will contain from 12 to 18 per cent. more iron. The unit freight cost is thus about 86 per cent. of the unit freight cost of the Lake ores.

Based on sintered Adirondack concentrates, there is.

at present quoted prices, a differential of about 33 per cent. in favor of Lake ores.

The writer can see no warrant for this differential. In estimating the possible ore reserves of the gray gneisses, the writer takes no account of the possible "blind deposits" (possible ore bodies which do not outcrop) in the 8,250 square miles of the Adirondack gray gneiss area. The estimate is confined wholly to the structural lines of the more or less operated mines in the 250 square miles of the six sections described. These structural lines are exhibited not only in the gray gneisses themselves but in the ore bodies as well. The strict conformity of the ore bodies to the dip, pitch and strike of the gneisses, as indicated by the foliation of the gneisses, is the only practical guide beyond actual exploration.

The Chairman (Mr. William A. Rogers): Are there any gentlemen who desire to discuss this paper? If not, we will pass on to the next paper on "Methods of Using Fuels in Open-Hearth Furnaces," by Mr. Herbert F. Miller, Jr., Assistant Superintendent, Lackawanna Steel Company, Buffalo, N. Y.

METHODS OF USING FUEL IN OPEN-HEARTH FURNACES

HERBERT F. MILLER, JR.

Assistant Superintendent, Lackawanna Steel Company, Buffalo, N. Y.

The Institute has been fortunate in recent years in having presented to it many very able papers on the open-hearth process. These papers have covered a wide range of the subject so thoroughly that at first one wonders whether there is anything left to discuss. Fortunately, however, the truth about any subject is inexhaustible and that fact gives us a reason for relating the various experiences and experiments concerning open-hearth construction and operation which have come under our observation.

About ten years ago I was in charge of a small open-hearth furnace plant where oil and natural gas were used for fuel. At that time the furnaces were slow and had high fuel and repair costs. These unfavorable conditions in reality afforded a splendid opportunity to experiment.

One of the furnaces was of the producer gas type with a single brick gas port. Oil was used in this furnace for fuel and was introduced through a water-cooled tuyere which projected across the uptake and terminated just short of the nose of the port. The time of heats made with this method of installation averaged 6½ hours. It was thought that if the water-cooled tuyere was pulled back, the flame having more distance in which to travel before reaching the hearth, would be in better shape to do its work.

Over a period of some weeks the burner was gradually pulled back, but no very marked change in the appearance of the flame occurred until it was decided to place the end of the burner projecting above but not entirely

across the uptake leading into the gas port. To make the matter clear, it may be stated that the furnace had two air uptakes and a gas uptake, which, however, was used to transmit air to the gas port, so that in reality there were three air uptakes at each end of the furnace.

Fig. 1 shows a producer gas furnace equipped with water-cooled oil burner. The tip of the oil burner was moved back from point A to point B as shown in the diagram.

With the burner in the position last described, there was a most startling change in the appearance and power of the flame. The flame turned to a pure dense white such as I had never before seen. The time of the heats

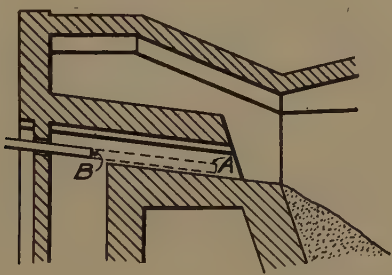


Fig. 1.

dropped to an average of 4 hours, 2½ hours faster than formerly. Magnesite brick in the bottom of the port melted together; the arch of the port melted and the roof of the furnace burned quite easily. Of course this method of burning fuel could not be continued under the construction then in use, as the furnace would soon have burned down. The uptake leading to the gas port was blocked off and the furnace proceeded in the normal way. I have repeated this experiment with other furnaces and have had the same results.

The first thought suggested is that this method is not a practical one to use as the open-hearth furnace brickwork will not stand the temperature. Let us first examine the facts surrounding this experiment. The oil was introduced into the furnace at about 65 pounds

pressure per square inch, and atomized with steam at a pressure of 65 to 75 lbs. per square inch, blown through an ordinary type of oil burner. The great speed at which this mixture went through the gas port caused it to act as an aspirator for the preheated air rising up the uptake leading into the gas port. This highly heated air was hit at right angles by the stream of vaporized oil and the two united under pressure and at great speed in a mixing chamber of small cross section.

These conditions approached the ideal for producing a flame of intense heat and perfect combustion. Here was given the idea for the development of the power of a flame in an open-hearth furnace. The principle being to put both preheated air and fuel under high pressure separately and then unite them in a mixing chamber of small cross section before flowing into the hearth of the furnace.

On another furnace where natural gas was used for fuel, a very wide gas port was installed. The combustion of the flame in this furnace was very good, but owing to the wide port, the flame control was poor. This resulted in a high brick cost as the roof was easily burned. The time of the heats with this design of port averaged about $6\frac{1}{2}$ to 7 hours. It was thought that if the port were made considerably narrower a flame with better control would be had.

A furnace was built along these lines and the control of the flame was secured as had been planned, but the depth of the gas layer was so great that the flame was smoky on the bottom and would not develop the temperature required at the point where it was needed. This experiment caused speculation as to whether a port could be designed which would embody the good qualities of both the wide and narrow port.

An experiment was made for solving this problem of combustion. A pipe was introduced into the port with one end well down on the slope of the gas port and the other projecting into the air uptake. The draft of

the furnace pulled air through the pipe introducing the air under the layer of gas as it flowed through the port. The flame changed from a smoky one to one of pure white.

As soon as it was possible to do so, a port was built where this feature of combustion was embodied. The gas was introduced to the port through two pipes terminating on opposite sides of the port and at right angles to the center line of the gas port. Under the port slope several by-passages for air were provided, one end of each passage terminating in the air uptake and the other end well down in the gas port. Thus the flame was introduced into the furnace between an upper and lower layer

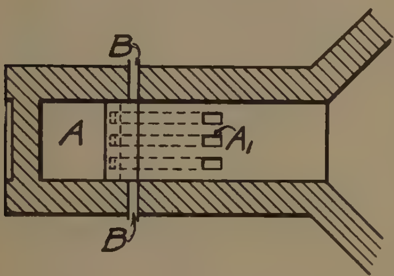


Fig. 2.

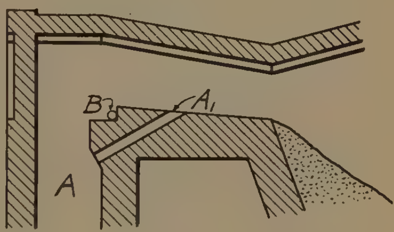


Fig. 3.

of pre-heated air. These passageways being at an angle with the bottom of the port made them somewhat difficult to keep clean so that on a later design the by-passages were made parallel to the bottom of the port.

Figs. 2 and 3 show furnace designed for natural gas for fuel in which part of the air is by-passed underneath the layer of gas through openings A1 from air uptake A. The gas inlet pipes are shown at B.

The first installation, however, developed an interesting fact: in cleaning out these by-passages, compressed air under a pressure of 75 pounds was used. A trial was made to see how much deflection the flame would have if air under the above named pressure was introduced into the by-passages and under the layer of gas. Instead of causing any deflection of the flame toward

the roof, the flame actually flowed into the furnace at a lower level and in a much more compact form. This showed that compressed air, if rightly applied, could be introduced both above and below a gas flame without injury to the furnace brickwork.

The cross section of the port being very much less in its nose than at the uptake gave a flame of great speed as it issued from the port, but with the introduction of compressed air the speed of the flame was still further increased. Without the use of compressed air, however, this furnace showed remarkable results: 429 heats were taken off a 9 inch roof. The heats averaged slightly less than 4 hours and the gas consumption averaged 2,800 cubic feet per ton. The furnace was only a small one, the charge having a total weight of 30,000 pounds per heat. Cold iron was used and 15 per cent. of limestone was charged. The steel was made into castings.

Later on, the same idea of mixing air with the gas was tried out on furnaces using producer gas for fuel. The first experiments along this line had by-passages from the air uptakes to the gas port. This was unsuccessful, as the pressure of gas from the gas port caused the gas to flow back through the by-passages into the air uptakes. This showed very clearly that in order to mix the preheated air with producer gas, the air must be introduced into the gas port under a pressure higher than that of the producer gas, but as the Company for which I was working at that time was unwilling to furnish the proper means for producing this action, the development of the idea was not pushed by me until a few years later.

A brief description of these experiments was published in the Iron Age in 1912.

Figs. 4 and 5 show furnace designed for producer gas for fuel in which the air is by-passed through the diagonal passages A1 from the air uptakes A to the gas port.

In 1917 and 1918 the thought again came to develop some means of getting a better combustion in open-hearth furnaces and as a result of experiments the circular

water-cooled port in use at the Lackawanna Steel Company was developed. This port has given excellent results in combustion and has decreased the rebuilding cost about 20 cents per ton.

One means of using compressed air with open-hearth fuel is being developed, as all know, by the Egler and McKune systems. From the outset these systems have each given excellent results in increasing production and reducing fuel costs. Some operators, however, have a doubt as to whether the use of compressed air with the fuel will not tend toward excessive rebuilding.

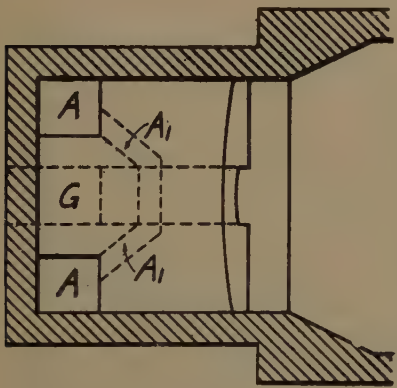


Fig. 4.

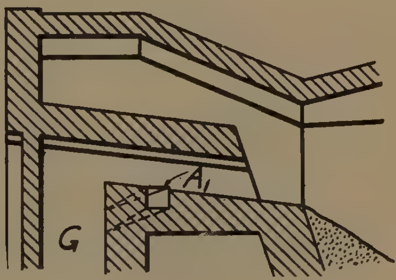


Fig. 5.

Again the point is brought up, as in the experience that I had some ten years ago with the oil furnace, of being able to develop a high temperature and intense flame, but not have a furnace lining that would resist the heating action of the flame. Here is a condition which would seem to limit the development of the open-hearth furnace, but is not this seeming limitation a hand pointing out the road to a further necessary evolution in open-hearth furnace design? One cannot help but think that the construction of open-hearth furnaces will be developed along the lines that had to be made to produce the modern high-power blast furnace. By this is meant that the hearth and end walls, including the roof, will

probably have to approach in similarity the construction of the bosh of a blast furnace, having roof and wall coolers alternating with the brickwork. The present pressures on both air and gas are much too low, and I see no reason why these should not run up into the pounds instead of the ounces per square inch.

We have but to look to the acetylene burner, see the pressures used and the rapidity of work done under

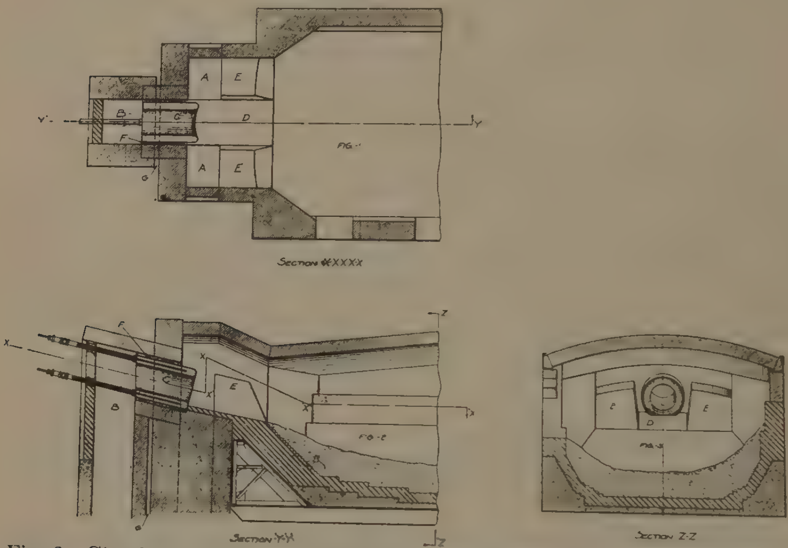


Fig. 6—Circular water-cooled port in use at plant of Lackawanna Steel Company. A, air uptakes; B, gas uptake; C, port cooler; D, combustion chamber; E, blocks; F, ground silica brick packing; G, air space between gas and air uptakes.

these pressures, to sense the possibilities which may be developed in an open-hearth furnace with high pressure in both air and gas. Furthermore, the blast furnace may also teach us that with proper sealing of the doors, the sheeting in steel plate of the walls, air and gas may be introduced into the furnace under high pressure, through small orifices and exhausted by mechanical means without the necessity for intermediate dampers. I have no doubt that heats charged with scrap and cold

pig iron can be tapped in 3 to 4 hours after starting to charge, when conditions of high pressure air and gas are developed.

It is apparent that we have scarcely scratched the surface of the field in which the ideas for developing power of open-hearth fuels are hidden.

THE CHAIRMAN (Mr. William A. Rogers): Mr. Miller's paper will be discussed by Mr. M. J. Devaney, Superintendent, No. 2 Open-Hearth Department, South Chicago Works, Illinois Steel Company, South Chicago, Ill.

Discussion by M. J. DEVANEY

Superintendent, No. 2 Open-Hearth Department, South Works, Illinois Steel Company, South Chicago, Ill.

Mr. Miller, in his closing remarks, stated that we have scarcely scratched the surface of the field where the ideas for properly burning fuels in the open-hearth furnace are hidden. This may be true, but it must be admitted that within the past two or three years more time, thought and study has been given to the question of combustion in the open-hearth furnace than ever before in its history. A number of methods have been tried at several different plants, and, with open-hearth men and engineers concentrating their work and thought on the subject of better combustion, it is to be expected that many different methods will be used in the immediate future. Some of those methods used in the past have proven more or less impractical on account of various reasons, and more especially on account of lack of flame control. This will probably also prove true of some of the methods that will be tried in the future.

It is agreed that a rapid and complete combustion is of prime importance, but it must be kept in mind that, with the hot flame temperatures coincident with such combustion, the question of flame control is more important than ever before; and if such control is lacking, the results will prove more costly than advantageous.

Such adequate flame direction and control is more easily accomplished with liquid fuel, such as oil or tar, than with producer gas, yet even with liquid fuel, it may be said that in most plants where used it has been found that a material percentage of the fuel leaves the combustion chamber of the furnace unburned. This lack of complete combustion is usually due to two causes: first, poor atomization of the liquid fuel itself; and, second, improper amount of air and improper distribution of the air relative to the fuel column.

Atomization of the Fuel

Tar is a very heavy, viscous fuel and is more difficult to properly atomize than is fuel oil, even though the oil used for commercial purposes today is not the thin, inflammable oil of a few years ago. The heating of tar or oil is very essential and effects quite a saving in the fuel consumption. The temperature to which the fuel oil should be heated depends a good deal upon the character of oil used. Temperatures ranging from 120° to 250° F. are used. At our plant, 160° to 170° F. for oil and approximately 140° F. for tar has been found to give the best results.

For the atomizer, commonly called burner, to function properly, the atomizing element, which is usually steam, must be brought into contact with the fuel in such a manner that the fuel is broken up into the finest of particles. There are numerous ways in which this is done, or partially accomplished. The ordinary type of atomizer or burner used for open-hearth work is usually constructed so that the column of fuel leaving the nozzle is simply surrounded by steam, with both the steam and fuel traveling in the same direction. The steam in this case imparts velocity to the fuel column but does very little atomizing. Therefore, a large amount of excess steam is used and more fuel than necessary is consumed, as a large percentage of the fuel passes on through the fur-

nace unburned. A test made on an open-hearth furnace using this type of atomizer showed an average steam consumption of 5.8 pounds of steam per gallon of tar, and on a similar test with fuel oil an average of over three pounds of steam was used per gallon of oil.

An atomizer has been developed at the South Works of the Illinois Steel Company, known as the Krause Atomizer, whereby by accurate tests on different furnaces the fuel consumption has been materially reduced, while the steam consumption per gallon of fuel has been reduced to about one-half.

The principles of this atomizer or burner are largely different from those of the conventional type which were in use at this same plant for years previous. The steam casing is built similar to a Venturi tube or meter at the throat, where the cross section is of the smallest diameter, which imparts a high velocity to the steam with lower pressure. The fuel is emitted at this point in a disc-like form at right angles to the steam. All the steam must, therefore, pass into and through the disc of fuel, thereby producing a mechanical action between steam and fuel that insures perfect atomization. The steam, on account of its high velocity and its flow being in line with the burner pipe, conveys the atomized fuel into the furnace. With this design 100 per cent. of the steam and 100 per cent. of the fuel used comes into action, and for this reason this burner seems to be the most efficient of any that has come to my attention.

A series of tests were made in 1920 on a 200-ton tar burning furnace, to determine the average steam consumption. The saving was found to average 2.90 pounds of steam per gallon of tar. Computing the amount of fuel this furnace used in that year, were it equipped with the Krause burners for that period, the saving in steam used on this furnace would have amounted to more than $5,000.

A 50-ton Venturi-type furnace equipped with Krause burners made a run some time ago that showed a distinct

fuel saving, making a total of 38,000 tons of ingots with an average consumption of 31.5 gallons of tar per ton of ingots. This included all heating up, bottom repairs, etc.

A plant in Pennsylvania recently installed these burners on five furnaces and after a careful test reported that their saving on tar amounted to seven gallons per ton of ingots.

Distribution of Air

It is equally important to have a proper mixture of air with liquid fuels as with producer gas. To accomplish this the furnace should be so constructed that the incoming air is driven into a quick mixture with the incoming fuel, thereby producing rapid and complete combustion.

With the use of the conventional fuel burner, it has usually been found desirable to locate the mouth of the burner near the end wall of the furnace in order to effect combustion quickly enough on the furnace hearth. With the improved atomization afforded by the Krause burner and the proper air distribution obtained on the 50-ton Venturi furnace previously mentioned, it was found necessary on account of more rapid combustion and higher flame temperature to move the mouth of the burner about four feet closer to the furnace hearth.

It might be well to mention another cause for poor atomization. When a water-cooled jacket is used to protect the burner, many times the cooler is built so that the cooling water comes into direct contact with the pipe that carries the atomized fuel. In this case the cooling effect of the water tends to condense the steam and partly liquifies the atomized fuel.

There are several simple ways by which this bad feature can be overcome and still have the necessary water-cooling to protect the burner pipe. One such construction employs a water-cooled barrel, having an inner diameter considerably larger than the outer diameter of the

burner pipe used to carry the fuel from the atomizer to the mouth of the water-cooled barrel.

Mr. Miller mentions the possibility of constructing and operating an open-hearth furnace along lines similar to those of the blast furnace. He suggests that the air and gas enter such an open-hearth furnace under very high pressures through small orifices and that the products of combustion be exhausted without the use of any auxiliary passageways as are used in the McKune and Egler types of furnace.

If he has in mind exhausting the waste gases through the same small openings used for incoming purposes, one of two undesirable features would be encountered, namely, rapid destruction of the orifices or excessive water-cooling. If we assume it possible to provide suction enough on the outgoing end of the furnace to exhaust the gases through such small openings, the concentration and the high velocity of the products of combustion would very quickly destroy the orifices unless they were provided with an amount of water-cooling which would prove detrimental to the furnace operation, on account of the amount of heat absorbed and taken away from the furnace system by excess water-cooling. While this type of furnace may or may not be what Mr. Miller had in mind, still it gives food for thought.

At the meeting of the American Iron and Steel Institute last fall, Mr. Ramage discussed the necessity of getting a better refractory for the open-hearth furnace to withstand the higher flame temperatures that are now being obtained. While I agree with Mr. Ramage regarding the desirability of having better refractories, which it may or may not be possible for the brickmakers to furnish, it will always be necessary, in the writer's opinion, to follow certain principles in the burning of fuels in the open-hearth furnace. These principles are:

First: Have the furnace so constructed that the air is driven into a quick mixture with the incoming fuel,

thereby getting a rapid combustion and high flame temperature.

Second: The air must be above and around the sides of the fuel column, providing a control which will protect the furnace roof and walls and concentrate the intensely hot flame upon the materials treated. Such a control will necessarily employ a fairly high incoming velocity and a low outgoing velocity.

The Chairman (Mr. William A. Rogers): Are there others who desire to discuss this paper? If not, we will pass to the last paper of the afternoon, "Gas and Air Valves for Open-Hearth Furnaces," by Mr. W. G. Bulmer, Superintendent, Open-Hearth Department, Ohio Works, Carnegie Steel Company, Youngstown, Ohio.

GAS AND AIR VALVES FOR OPEN-HEARTH FURNACES

WILLIAM C. BULMER

Superintendent, Open-Hearth and Bessemer Departments, Ohio Works, Carnegie Steel Company, Youngstown, Ohio.

As the early metallurgist had little if any knowledge of gaseous fuels, it follows that he knew nothing of their application in his furnace. His experience was confined to the burning of solid fuels, such as wood and charcoal, and later to the organic deposits of the earth, of which coal, peat and lignite are examples. It is reasonable to assume that one of his very first problems included the regulation of temperature, which he solved by the use of the forced blast of the bellows. With the increase of his knowledge he learned that a further regulation of temperature was necessary, and we find him placing a movable cover over his chimney, or a damper or slide in the flue leading to it, whereby the passage of the waste gases to the atmosphere might be constricted at will or as his process demanded. He augmented this by the use of doors covering the opening through which he introduced his fuel, and over the pit from which the ash was removed. These contrivances not only permitted him to govern his temperature, but they also provided a means whereby he could control the character of the reactions taking place in his furnace, and we find him able to produce a reducing atmosphere, where one of an oxidizing nature did not suit his process.

In the development of the early blast furnace, it was discovered that large quantities of useful fuel, escaping from the top in the form of a gas, might be utilized for preheating the blast air for the furnace. This was accomplished by burning the gas in a chamber, through

which the air was passed by means of cast iron pipes or conduits. From this grew the practice of burning the gas in a series of chambers and alternately passing the blast air through them before it entered the furnace. These inventions made possible the saving of more than one-half of the fuel otherwise necessary for the process.

The experiments of William and Frederick Siemens in the production of steel in reverberatory furnaces began as early as 1856. They found that they could not successfully obtain the results desired by the use of cold air in the combustion of their fuel, which led to the adoption of the regenerative principle characteristic of open-hearth furnaces. Higher temperatures and an economy in the consumption of fuel were a natural consequence.

As all regenerative types of furnaces require a periodic reversal of the flow of the gases through them, some mechanical agency must be employed to cause the change of direction. The simplest device for this purpose is the butterfly valve, and naturally it was the one first adopted. It served the purpose and would be the ideal contrivance if the material of which it is made did not become distorted through the expansion and contraction caused by the variation of temperature to which it is subjected. Its use for the regulation of the air has been more or less satisfactory, and in some cases it still survives as an adjunct to certain classes of air valves, but its application to the reversal of gas has not met with favor.

Apparently little effort was made towards the improvement of the early valves until the year 1889, when a water-cooled butterfly valve was installed at No. 2 Open-Hearth Plant of Carnegie, Phipps & Company at Homestead. The idea, of course, was to prevent distortion, but difficulty was encountered in keeping it water-tight and it was replaced by a cast iron one of the dry class. This, in turn, gave way to the double-seated mushroom valve in 1900.

The diagrams appended to this paper (see Figs. 1 to 24) are arranged to show the development of valves, and for each the inventor claims some superiority.

Minimum Resistance to Flow of Gases.

The chief requisites of a proper valve are an effective seal and an unrestricted passage. The choice of a valve requires most careful consideration, as upon the fulfillment of certain requirements depends the successful operation of the furnace. In order of importance we should consider, first, the valve having the minimum resistance to the flow of gases, combined with the least amount of leakage past the valve.

From investigation of installations now in use, it can be safely stated that the effective draft in the flue leading from the checkers will seldom be over 50 per cent. of that found at the base of the stack. To determine the cause of draft failure, in the early stages of the campaign on furnaces at South Chicago, measurements were taken throughout the entire system of flues between the regenerative chambers and the stack. The gas valve was of a well-known type used in conjunction with a butterfly air valve, and when measurements were taken in the flue on each side of these valves there was found to be a frictional loss amounting to 52 per cent. of the stack draft. This is not at all an unusual condition, as installations have been found where the effective draft in the checker flues was only 30 per cent. of that of the stack. In a heating furnace at South Chicago, on account of a difficulty existing in the draft, a considerably higher stack was built before an investigation of the conditions was made. As little improvement was found in the working of the furnace, a search was then made to determine the cause of the trouble and it was found that the loss of draft, due to the valve and turns leading to and from it, amounted to 72 per cent. of the stack draft. Obviously, in this case, the valves were altogether too small for

the furnace. I have known of measurements being made at various plants on the draft loss due to the valves, and in no case have I found it to be less than 27 per cent. and this on a furnace where the valves were of rather ample size. In another investigation as to draft and pressure conditions existing through a gas valve, portions of the producer gas port of the valve were found to show a negative reading. This indicated only that the churning of the gas in passing through the valve formed zones of eddy currents which resulted in a partial vacuum. The moving of the pressure testing pipe across the area of the valve port would show readings varying from .4″ to minus .1″ water column. Needless to say, the actual area of flow through the port was considerably less than the total area, which of itself was too small for the amount of gas to be handled. Not only did the four right angle turns, necessitated in the flow of the gas out of the flue through the valve and back to the flue, cause serious frictional losses, but the impingement of the gas on the extending water seal was also a detrimental factor.

Resistance to flow through the valves has a very bad effect on the operation of any furnace, as the slowing up in the time of heats and the final shutting down of the furnace on account of the clogging of the air checkers are largely due to the lack of sufficient draft to pull the waste gases through the restricted opening. The dirt will accumulate in inverse proportion to the draft at the checkers, and only a sufficient pull at all times will insure a sharp working furnace. It is not difficult to decide, therefore, that the type of valve to choose is one that will permit of the draft at the checkers being as near to that of the stack as possible.

In addition to the valves, another factor which should be considered with reference to a free flow of the gases is the directness of flue passage with the shortest possible length, not only between the furnace and the stack but also between the gas producers and the valves. Sharp turns in the flues, poorly designed valves, or a combination

of both, will have a very detrimental effect upon the working of the gas producers, as it requires excessive pressure to drive the gas to the furnace, resulting in poor gas and improper producer operation. Many installations of restricted valves with poorly designed flues will be unable to properly procure a sufficient supply of good gas to operate to the best advantage with the adoption of the present day sharp working furnace, but in many cases this can be materially improved by the adoption of a valve having unrestricted passage.

Advantages of the One-Way Valve

Valves may be divided into three groups, namely: one-way, two-way and four-way, depending upon the number of directions of gas or air passage through them. Those of the one-way group are the only ones which offer means of regulating the flow of gases to and from each checker chamber separately without additional equipment in the form of extra dampers or valves.

If a furnace is designed for proper distribution of the waste gases between the air and gas checkers, this distribution will not be maintained for long without proper valve regulation. The accumulation of dirt in the air checkers will add frictional resistance, which will decrease the proportionate amount of waste gases going through these checkers and the furnace will soon be thrown out of balance. By the use of a one-way valve, manipulation of the floor stands can be made to open the valve to any required degree, and at all times in the furnace campaign any desired proportion of the waste gases can be put through either of the chambers. The same regulation of the incoming gas can be made to offset the disadvantage of unequal port areas on either end of the furnace. This regulation should be particularly useful in a plant which does not run through Sundays. With only sufficient gas kept on the furnace during the Sunday shutdown to keep the

furnace hot, the air chambers usually become much colder than the gas chambers and it is not until two or three days later that the temperature of the chambers is properly balanced. With a single-way valve installation, the regulation can be made such that practically all the waste gases, during the period in which the furnace is simply being kept warm, can be caused to go to the air chambers, thus keeping them up to a much better temperature than would otherwise be the case.

Another advantage of a single-way valve is that it can be adapted to any desired flue layout and could often be readily installed to correct present difficulties, due to poor flue arrangement, with a poorly constructed valve that might be in use. For waste heat boiler work a valve giving straight line flow with a minimum of exposed water-cooling will give the best results. Not only does this type of valve insure higher waste gas temperature to the boilers, but because of their offering practically no resistance to the passage of the gases, they require less power for operating the boiler fan. The argument might be offered that where waste heat boilers are used, sufficient draft can always be obtained by the use of a sufficiently large fan, but this would be poor reasoning, for if between the stack and furnace ports certain frictional resistance can be tolerated, it is much better to have this resistance offered by a closer laying of checkers than by unnecessary resistance through the valves or with normal areas through the checker chamber. The less the resistance offered by the valves, the smaller the incoming and outgoing ports can be made, which will result in better combustion conditions.

Types and Classes of Valves

Valves may be of the following types: slide or damper, butterfly, mushroom and movable hood. They may be classed as dry, refractory-lined, water-cooled and water-sealed.

The slide and butterfly types may be of any of the classes or combination of classes, but the water seal is rarely applied to them. The mushroom type may be of any of the classes. The movable hood type is usually refractory-lined and water-sealed, although the refractory lining is sometimes omitted. In a general way the butterfly valve may be considered as a modified slide or damper, and we can state that the slide valve, of all those devised, offers the least obstruction to the passage of the gas through it. Invariably, in the other types, a change of direction in the path of the gas of from 90 degrees to 180 degrees, and in some case as much as 360 degrees, occurs, and the friction losses are therefore bound to occur.

In the dry class no attempt is made to cool the casting or plates of which the valve or its seat is made. The slide and butterfly are frequently of this character.

The refractory-lined valves are confined mostly to the slide, mushroom and movable hood types, although nearly all have the surrounding hood, where such is employed, lined with brick. Refractory linings are hard to hold in place because of the jar that accompanies the reversal, and no matter how tightly wedged when put in service the lining will eventually loosen and fall out.

The water-cooled valves embrace the slide, butterfly and mushroom types. They have the principal parts, including the seat, filled with moving water, whereby an even temperature within the member is maintained and distortion from expansion and contraction prevented. They are not always reliable in this respect and are particularly likely to fail after a short time when made of cast iron.

About the year 1914, experiments were begun with a water-cooled damper valve made of rolled steel plate and at the present time it is possible to procure a welded steel plate valve working on an inclined water-cooled seat, each having machined surfaces where contact is made, that will give a minimum amount of leakage and is so constructed that any expansion or contraction that might

take place does not tend to distort the valve and destroy the seal. Some trouble was experienced with the accumulation of a carbonaceous material on the face of the valve which might tend to cause leakage, but with the present valve the trouble has been so slight that it is being given very little consideration. The adoption of a refractory surface, where the valve is exposed to the producer gas, will materially aid in eliminating any slight trouble that might be caused from this source.

Water-sealed valves provide the most perfect seal that has as yet been devised and can be used effectively with the mushroom or the movable hood. In each case a projection of the valve is plunged into a basin of water of sufficient depth so that the liquid column will more than balance the difference of pressure within the conduit and the atmosphere or adjacent passageway. The glaring fault of this class of valve lies in the water evaporation that takes place from the basin; the passing hot gas picks up the vapor and is cooled to an appreciable extent. There is also more or less water splashed into the gas flues at each reversal. This not only must be evaporated, but coming in contact with the brickwork of the flue causes deterioration. At the Gary Works of the Illinois Steel Company, on some of their stationary producer gas furnaces, the change from a valve having exposed water and exposed water-cooled parts to one having a minimum amount of exposed cooling surface, resulted in an increase of temperature in the waste gases going to the boilers of approximately 180 degrees. This temperature difference checks up very well with the usual temperature drop found through the ordinary types of valves which offer a large amount of exposed cooling surface, and in one investigation I found the temperature to show a difference of 240 degrees. A similar change of valves at Wierton has resulted in their increasing the waste heat boiler output from 58 per cent. to 78 per cent. of rating. Wierton is getting this rating from their boilers on a low coal consumption, which, when their

furnaces are working properly, is in the neighborhood of 450 pounds per ton of ingots.

Another objection to the use of a valve having a water-sealed seat has been that it is always liable to leakage in portions that are hidden from the view of the furnacemen, and it is only when the effect upon the working of the furnace is noted that inspection, which in most cases is difficult, proves that the trouble is due to a crack in the casting, and it not infrequently happens that a negative pressure will cause a portion of the water to syphon from the basin into the flue. The substitution of welded steel plate seats for cast iron seats has to a great extent eliminated the trouble due to leakage, but the immersion of the valve into the water when the seal is made will remain a constant factor in the splashing of water over the edge of the seat and into the flues. The brick walls that form the flues and support the valve suffer from the effect of this moisture and the resultant weakening of the joints often causes leakage of gas from the gas passage into the waste gas flue, which often continues for a considerable length of time before becoming sufficiently bad to cause detection. The impact upon the seating of certain types of water-sealed valves is an added source of destruction to the seat, and not only do you have a serious loss, due to leakage of water into the flues, but in most cases it is necessary to stop the operation of the furnace until the seat can be replaced.

An added security is provided against gas leakage past the valve in one make in which the flues are completely separated by means of a brick-lined tube, acting on the same principle as a switch in a railroad track, whereby the flues are connected as desired and the change in the flow of gas controlled. The water in connection with this valve is of comparatively small area, open to inspection at all times.

For moving valves every known method has been applied, including hand power, hydraulic, pneumatic and steam cylinders, and electric motor. The latter method

is no doubt the most satisfactory, and its popularity will increase in the future. Whatever the mechanism employed, it should be of a sturdy character and able to withstand the strains that are put upon it.

The theoretical relation of the areas of gas and air valves and openings into the furnace has been discussed by numerous authors and for those who may be interested in this phase of the subject, reference is made to the paper on "The Principles of Open-Hearth Furnace Design," by Charles H. F. Bagley,* and also to the paper on "The Basic Open-Hearth Process," by Mr. F. H. Toy,† in which he states that practical experience has demonstrated that an air valve area of one square foot per ten tons of furnace capacity is adequate.

Much thought has been given to the development of a satisfactory water-cooled valve and seat, and to one having a perfect seal, but it would appear that with the exception of two of recent invention, i. e., one in which one end of a section of flue swings through an arc of a circle connecting adjacent flues, and the welded steel damper type having an inclined water-cooled seat with machined working surfaces, none measure up to the requirements we have stated for an ideal valve. Too much weight should not be given in the choice of a valve to the first cost, providing satisfactory operating conditions in all respects can be attained.

The water-cooled slide with inclined seat comes nearest to the perfection we are seeking. Its durable mechanical construction, including sturdy manipulating devices, all of which is easily accessible for repairs, combined with straight line flue passages, least heat losses, independent control of flow for each chamber, minimum leakage, adaptability to local conditions, small space required, minimum loss of fuel at time of reversal and low maintenance cost, recommends it to our serious consideration.

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*Journal of the Iron and Steel Institute, Vol. II, 1918, pp. 289-303.
†Year Book, American Iron and Steel Institute, 1920, pp. 319-362.

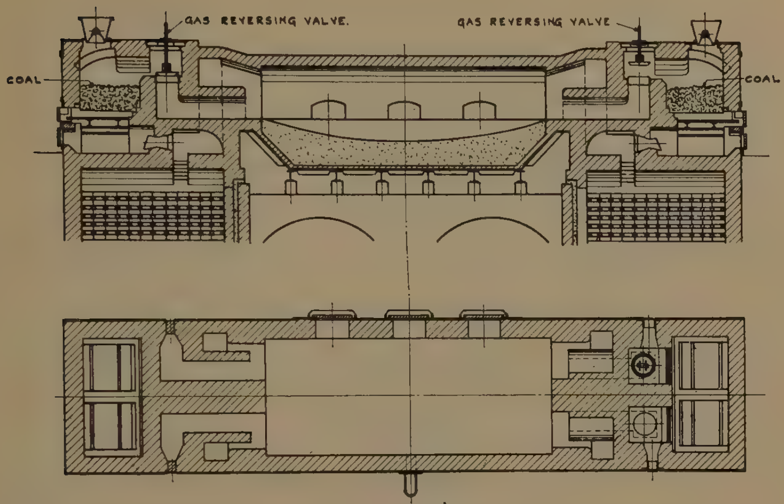


Fig. 1—Early type of open-hearth furnace, showing gas reversing valve.

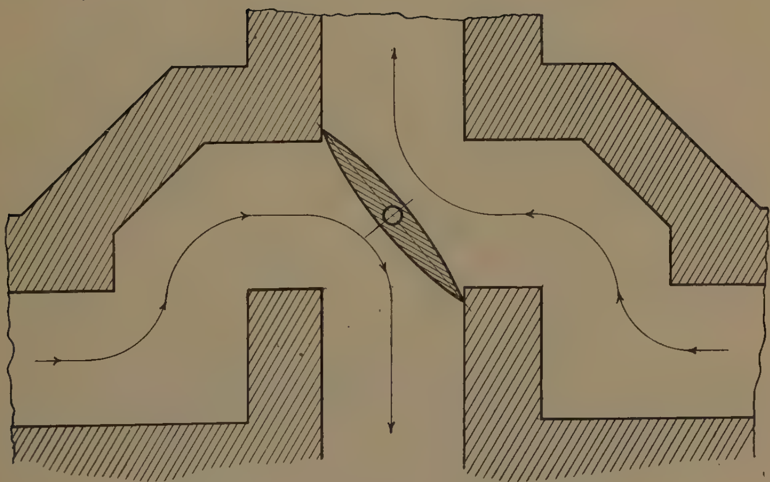


Fig. 2—Earliest type of Siemens reversing valve.

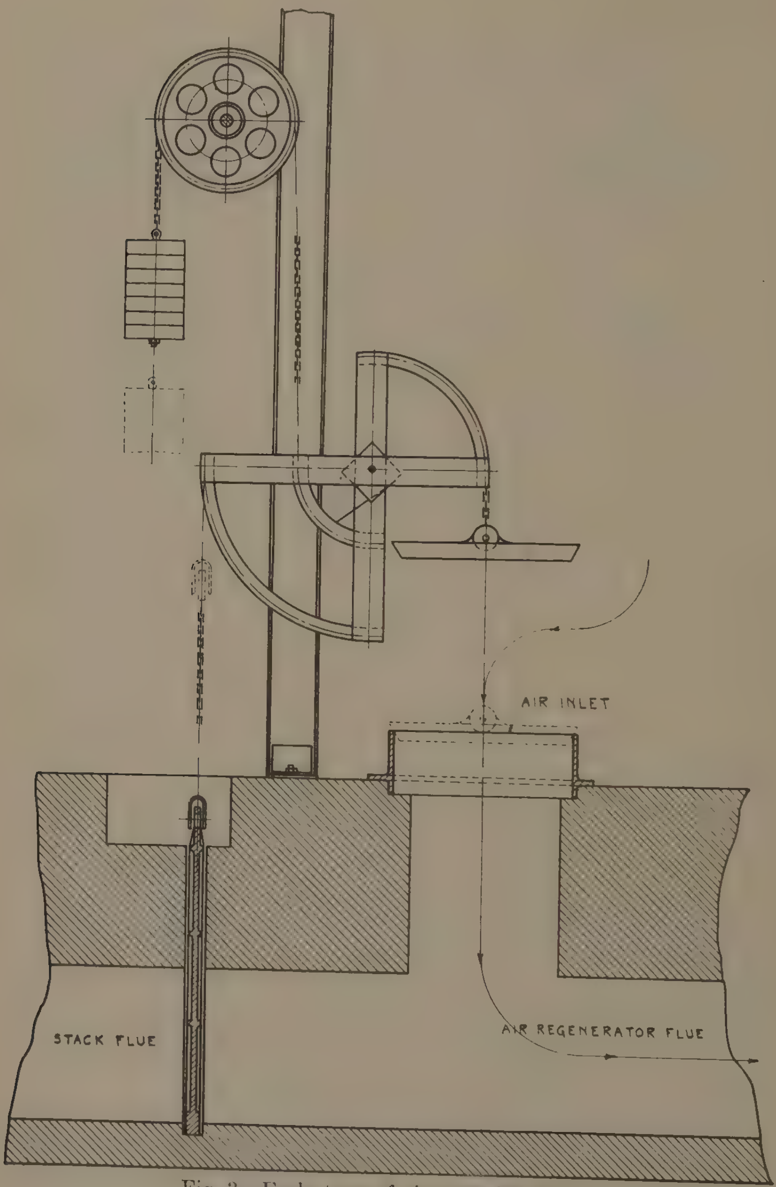


Fig. 3—Early type of air reversing valve.

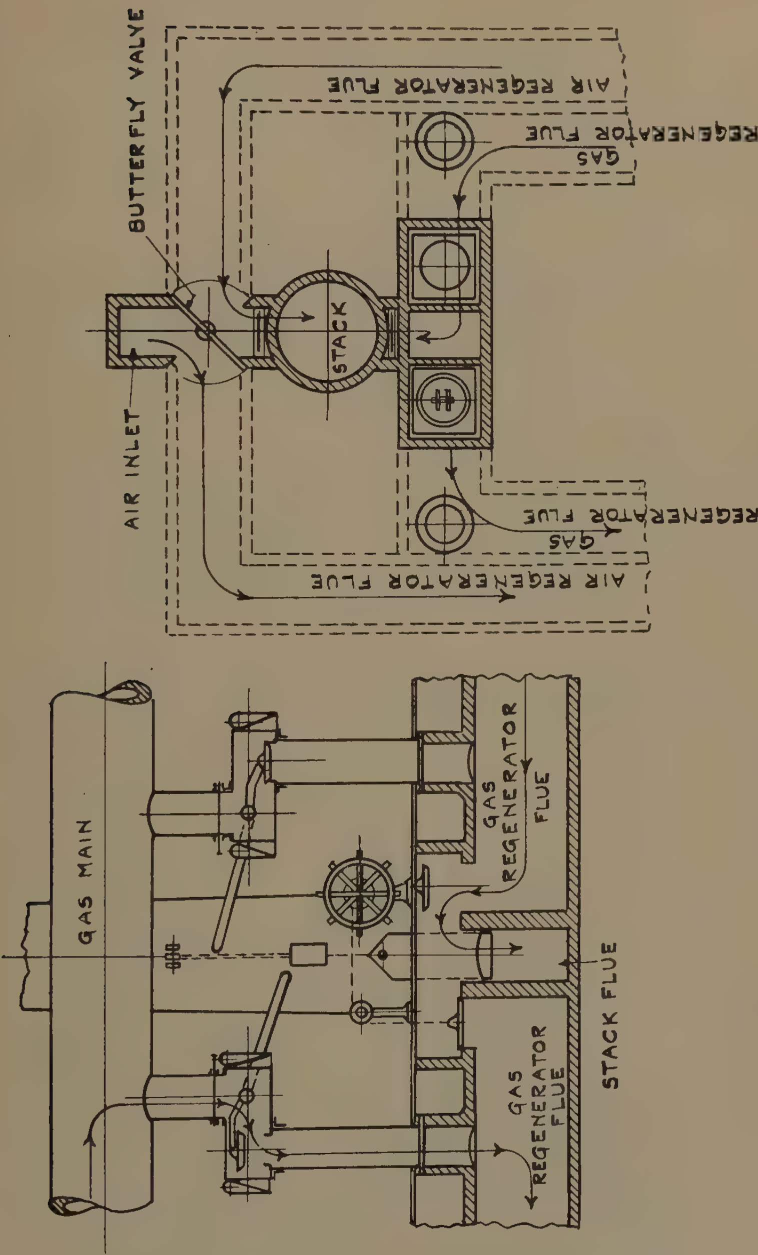


Fig. 4—Early type of gas and air reversing valves.

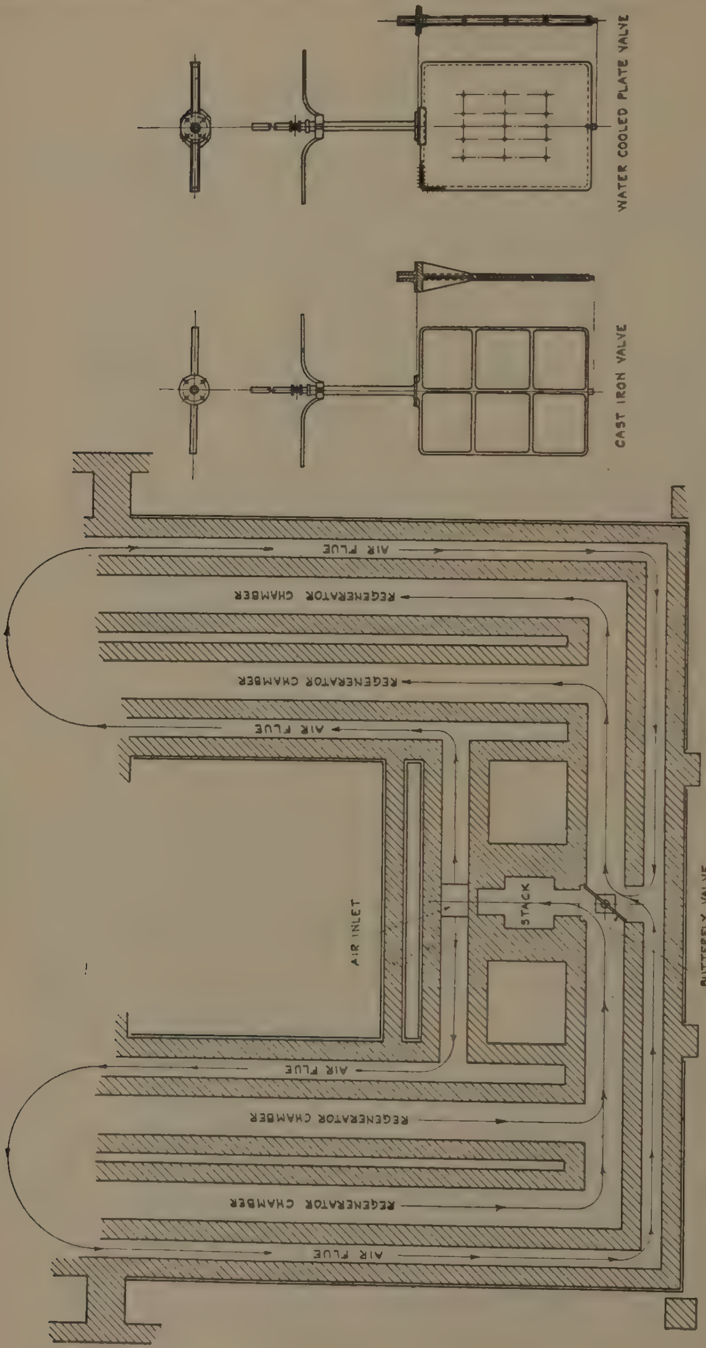
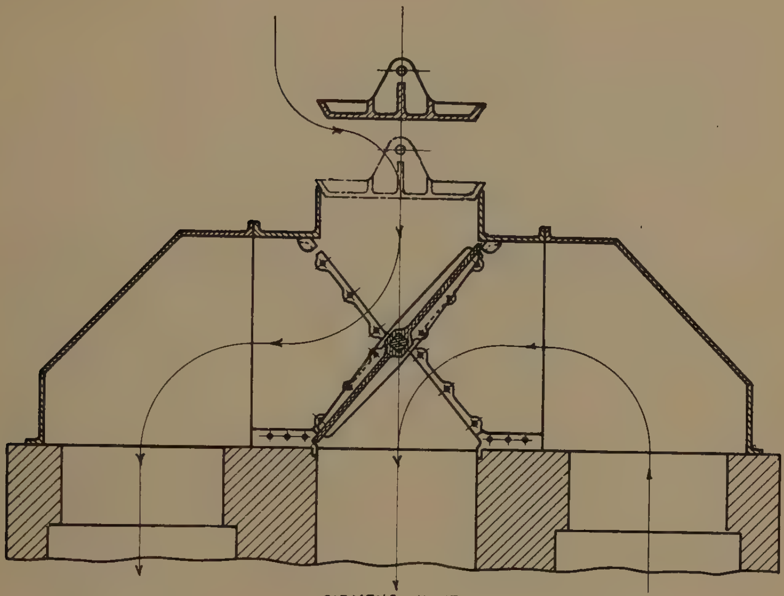
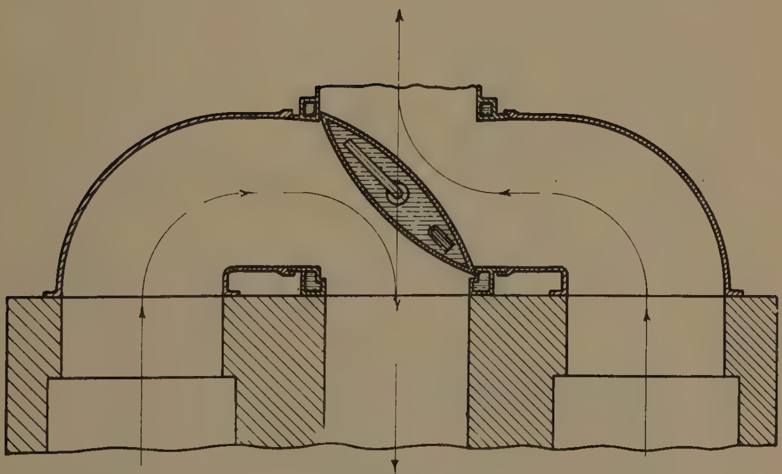


Fig. 5—Reversing valve and flue arrangement, Homestead Steel Works, Carnegie, Phipps & Company, 1889.



SIEMENS VALVE.



HIGGS VALVE

Fig. 6—Types of dry and water-cooled butterfly reversing valves.

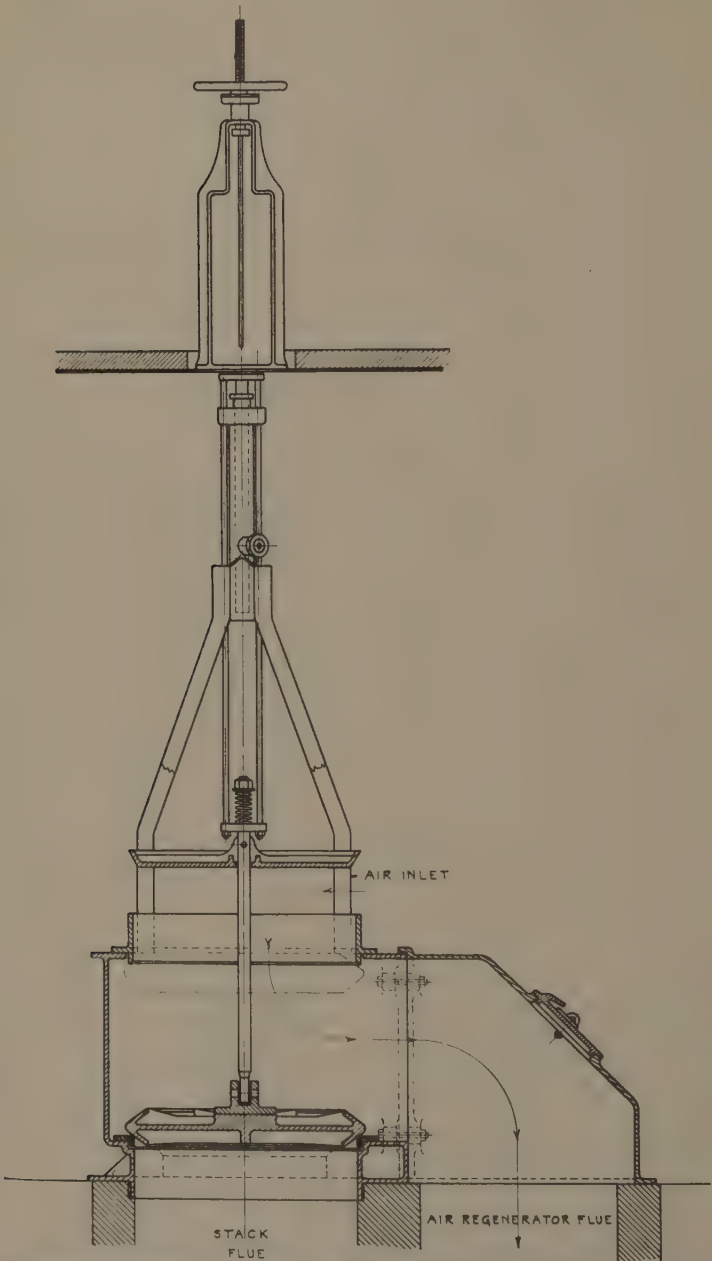


Fig. 7—McConnell air reversing valve installed at open-hearth plant No. 2, Homestead Steel Works, Carnegie Steel Company, 1901.

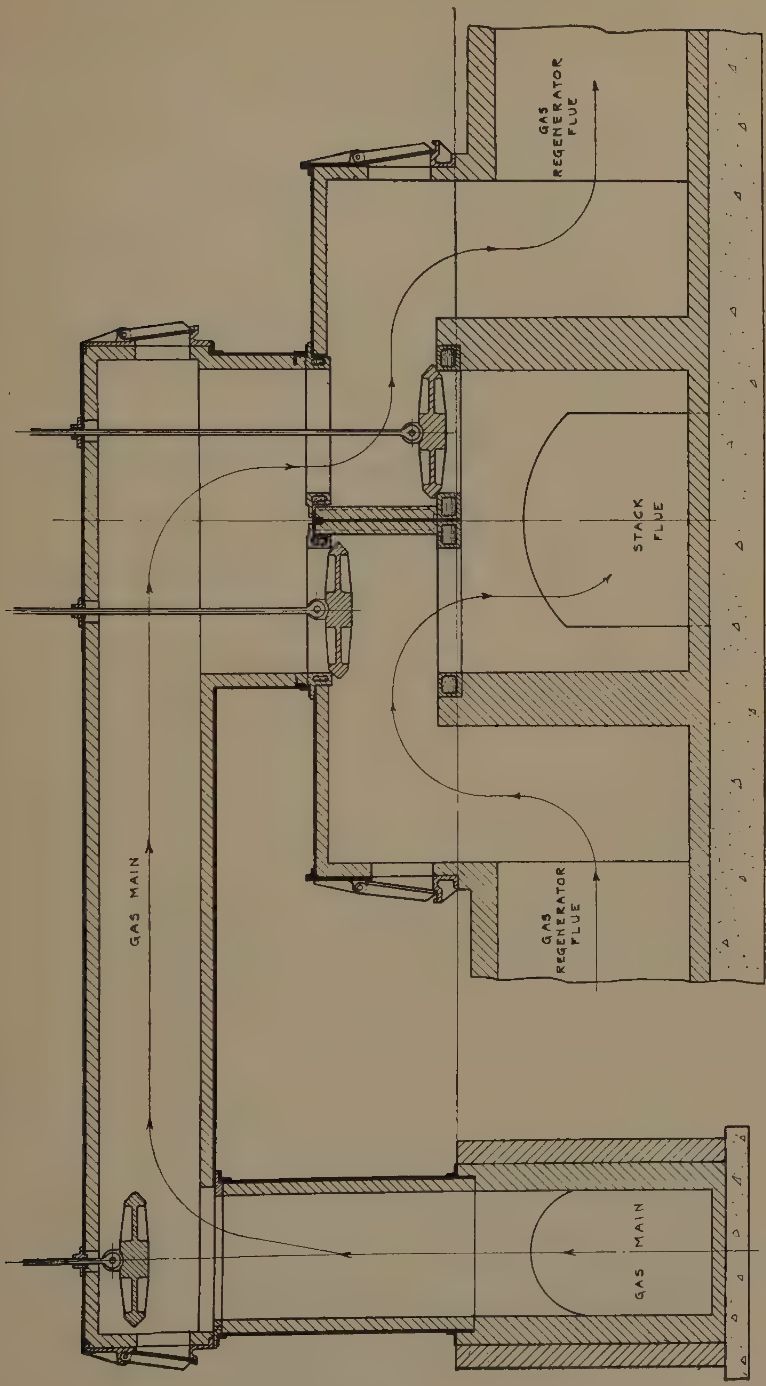


FIG. 8

Fig. 8—Arrangement of gas reversing valve, South Works, American Steel & Wire Company, Worcester, Mass.

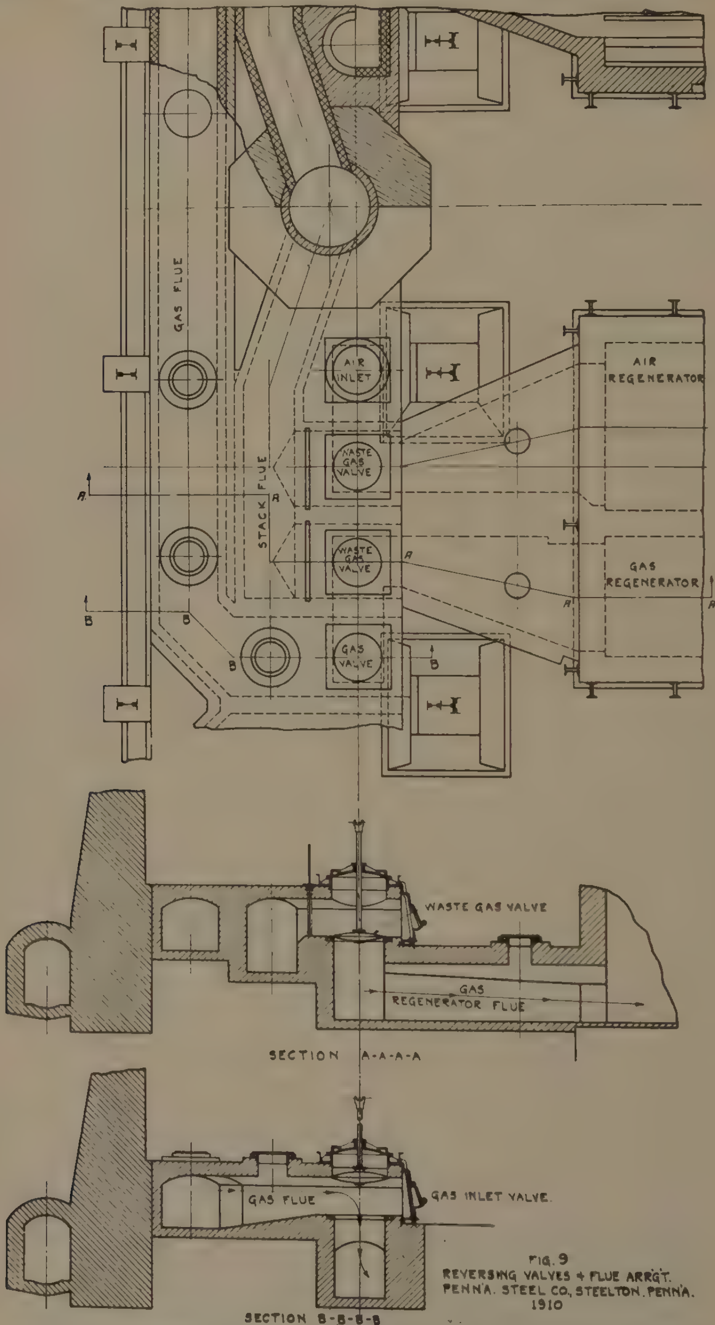


Fig. 9—Reversing valves and flue arrangement, Pennsylvania Steel Company, Steelton, Pa., 1910.

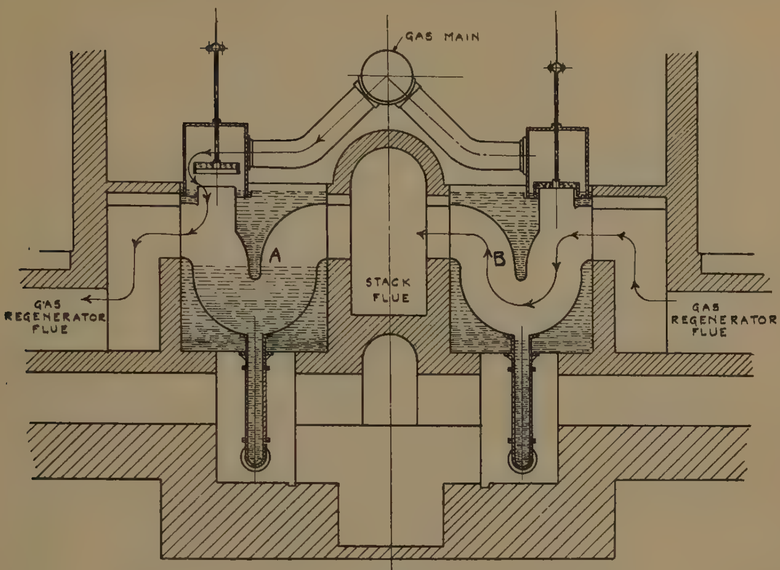


Fig. 10—Treat water-cooled gas reversing valve.

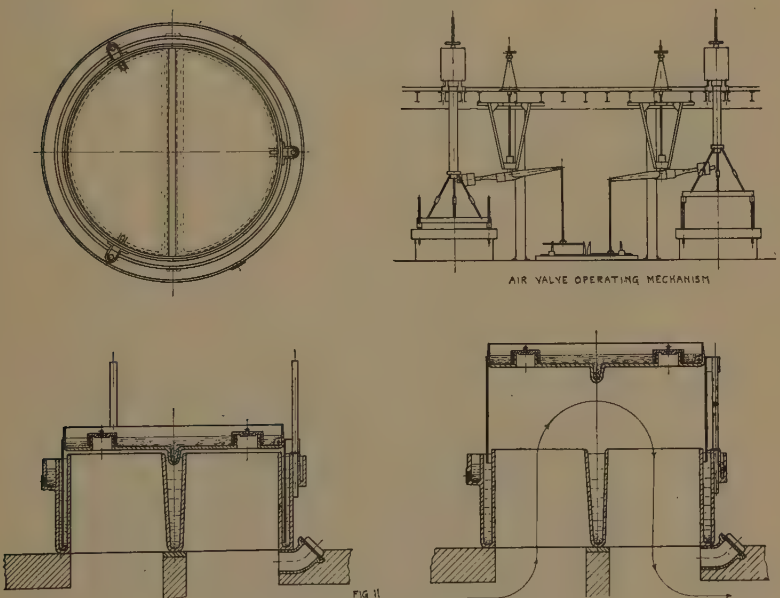


Fig. 11—The McKennan Valve.

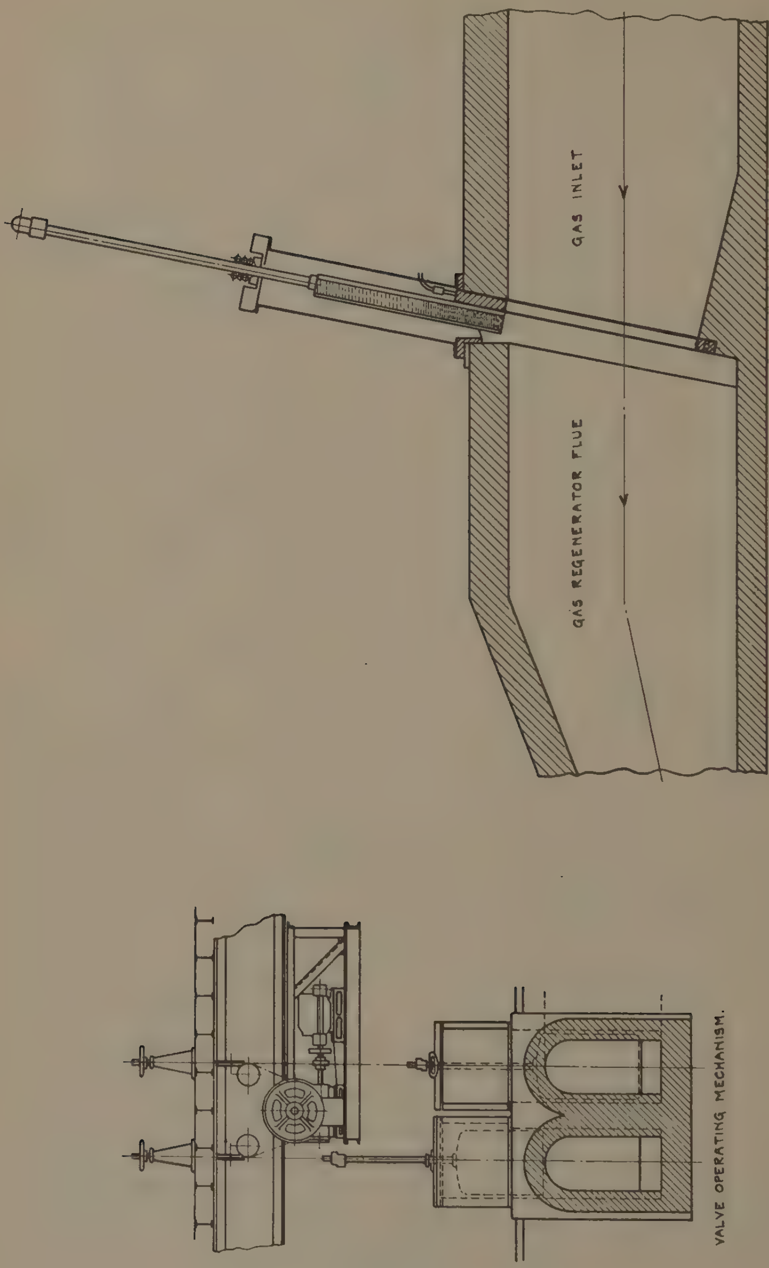


Fig. 12—The Knox Valve.

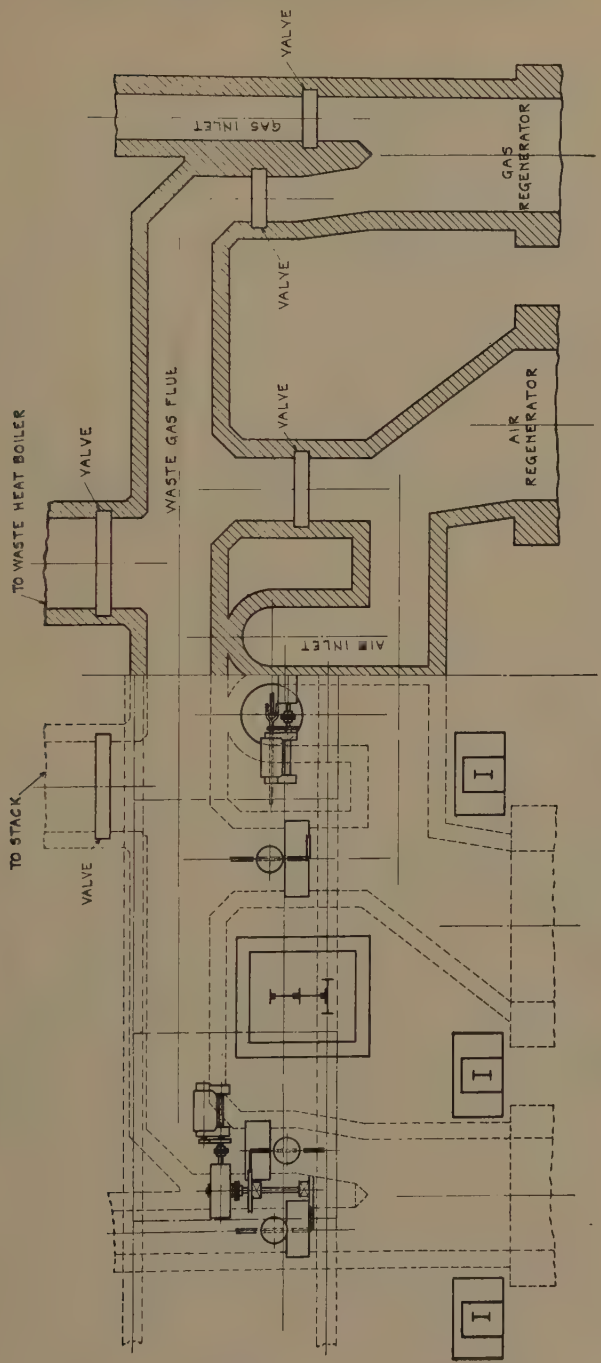


Fig. 13—Arrangement of flues for Knox Valves.

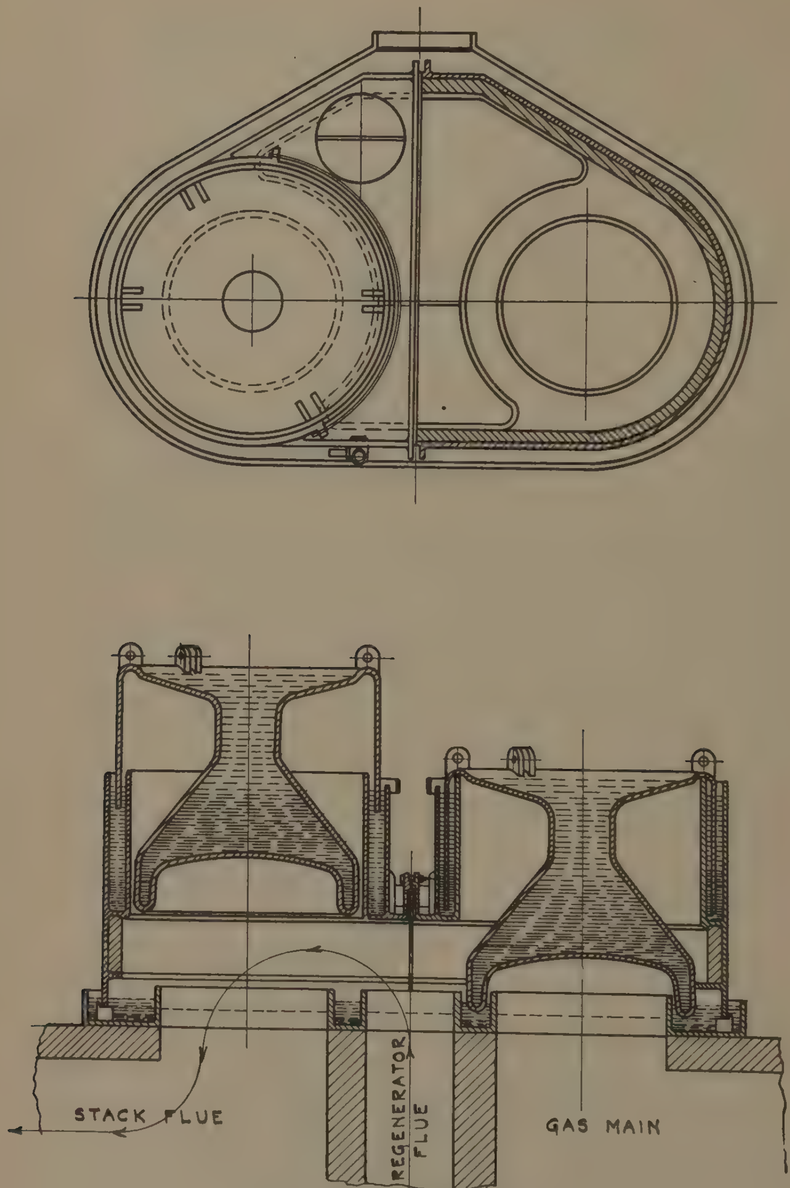
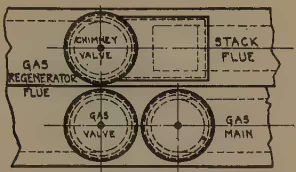


Fig. 14—The Ahlen Valve.



ARR'G'T. OF GAS + CHIMNEY VALVES.

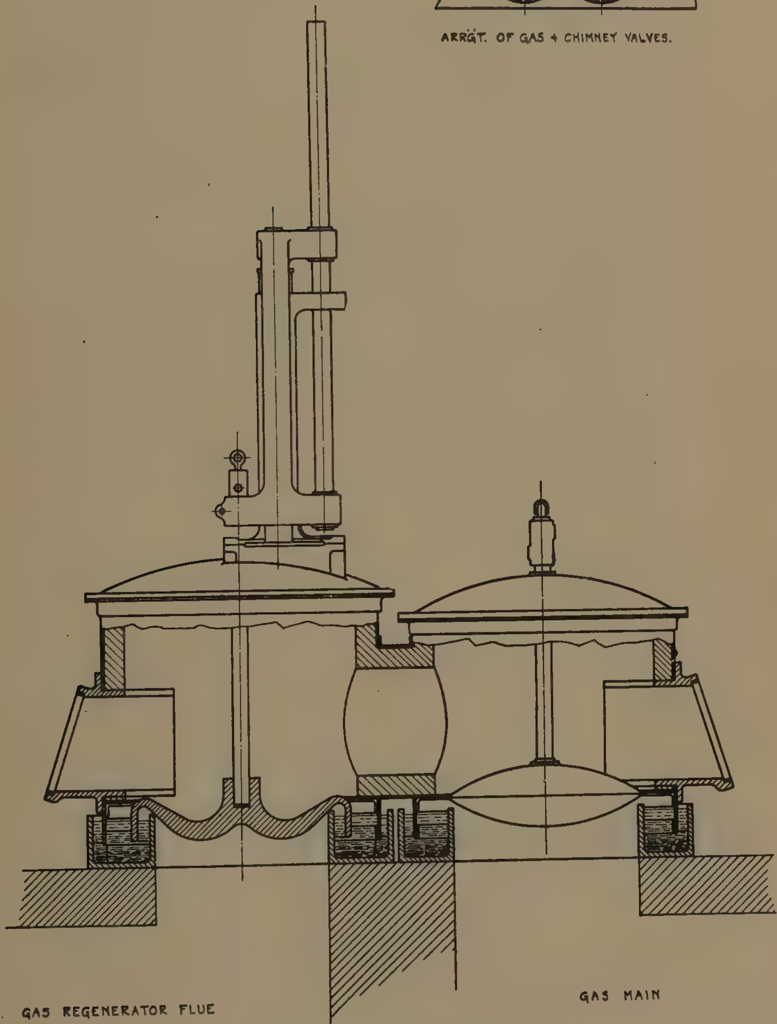


Fig. 15—The Monroe Valve.

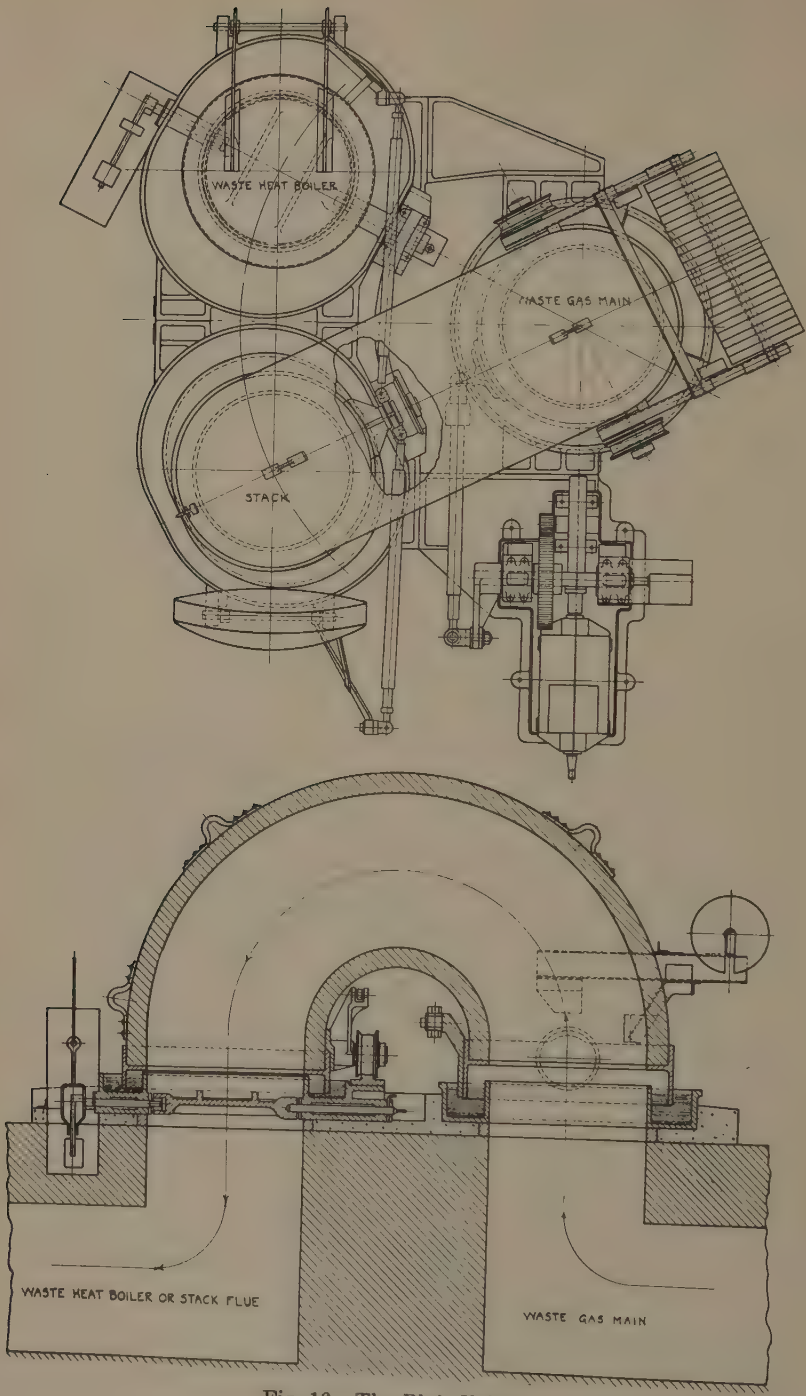


Fig. 16—The Blair Valve

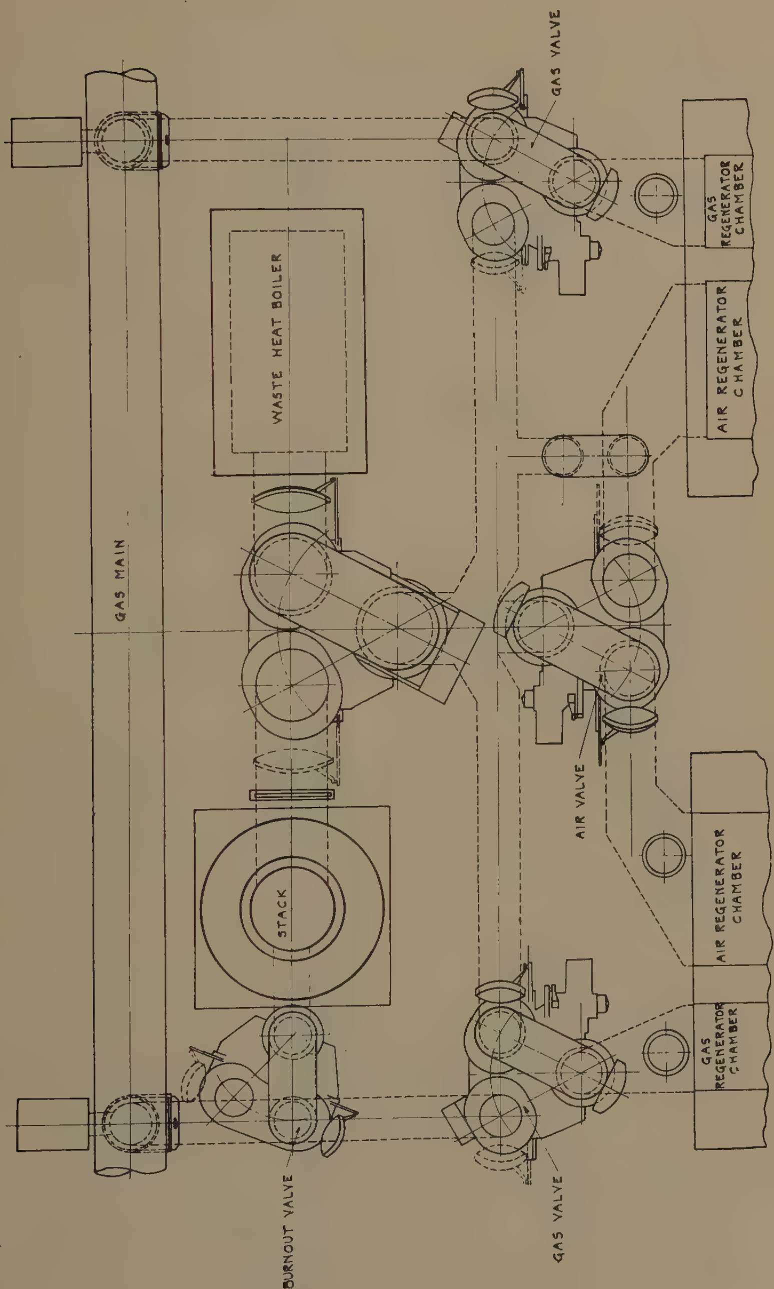


FIG. 17

Fig. 17—Arrangement of flues for the Blair Valves.

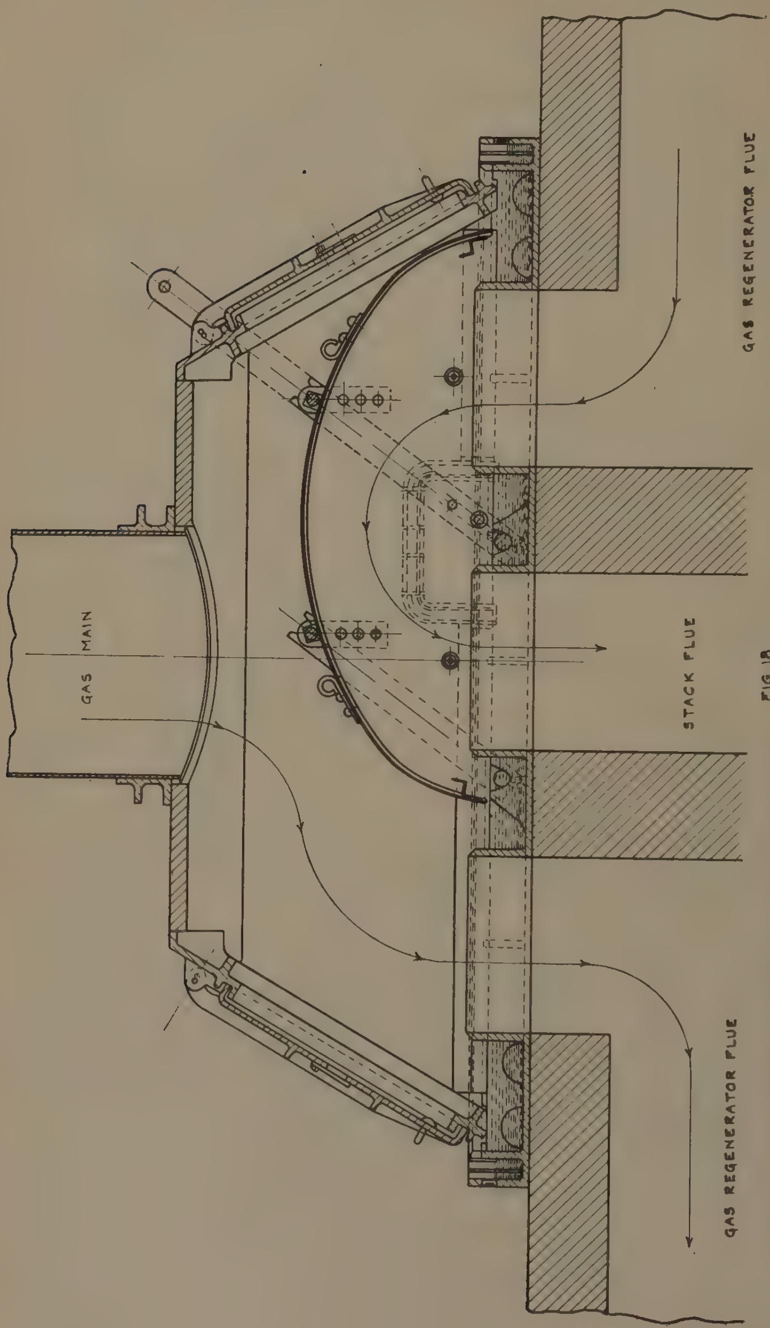


Fig. 18—The Forter gas reversing valve, South Works, American Steel & Wire Company, Worcester, Mass., 1900.

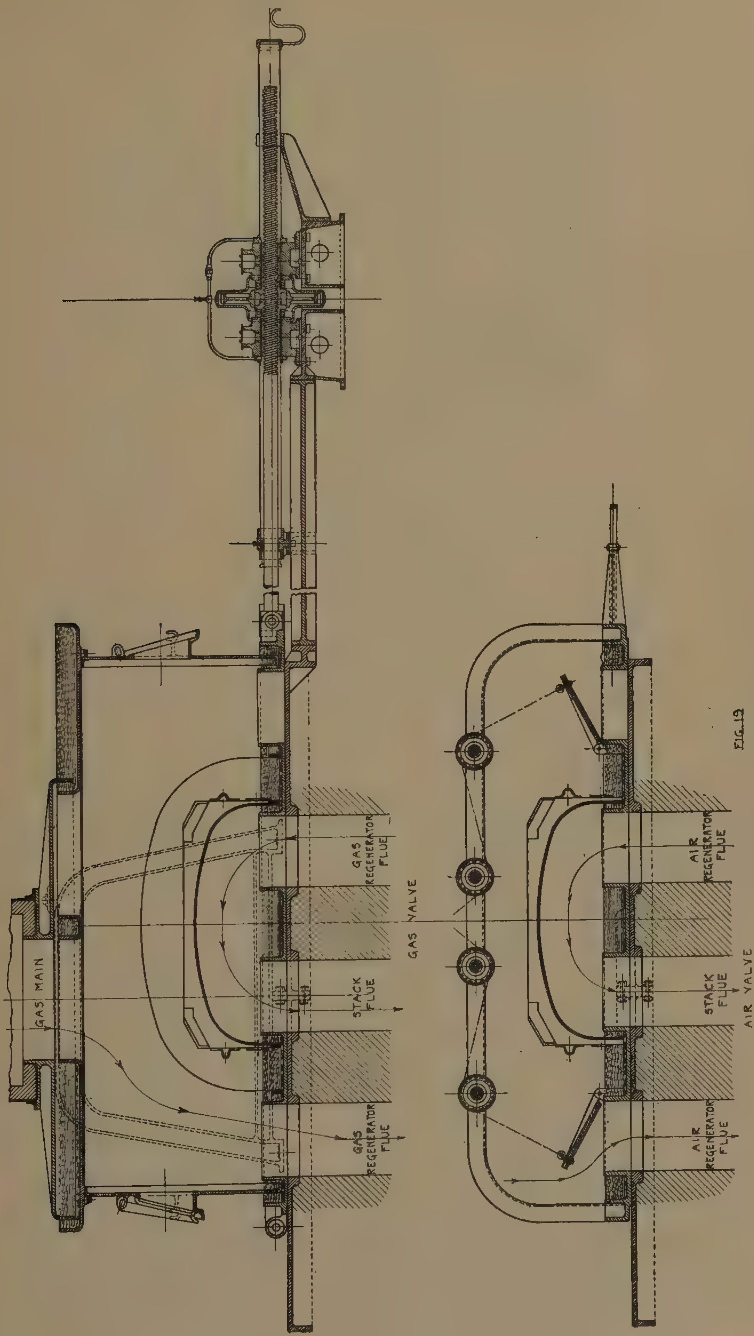


Fig. 19—The Schild gas and air reversing valve.

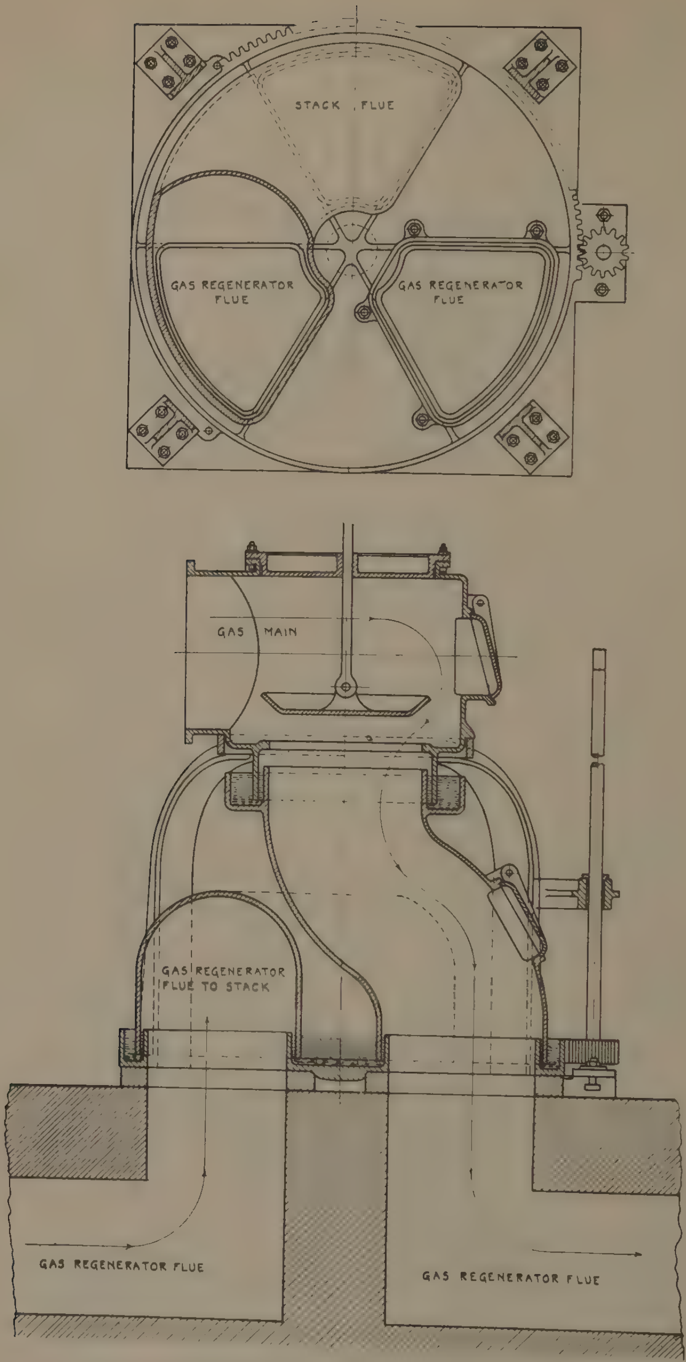


Fig. 20—The Schild revolving gas reversing valve.

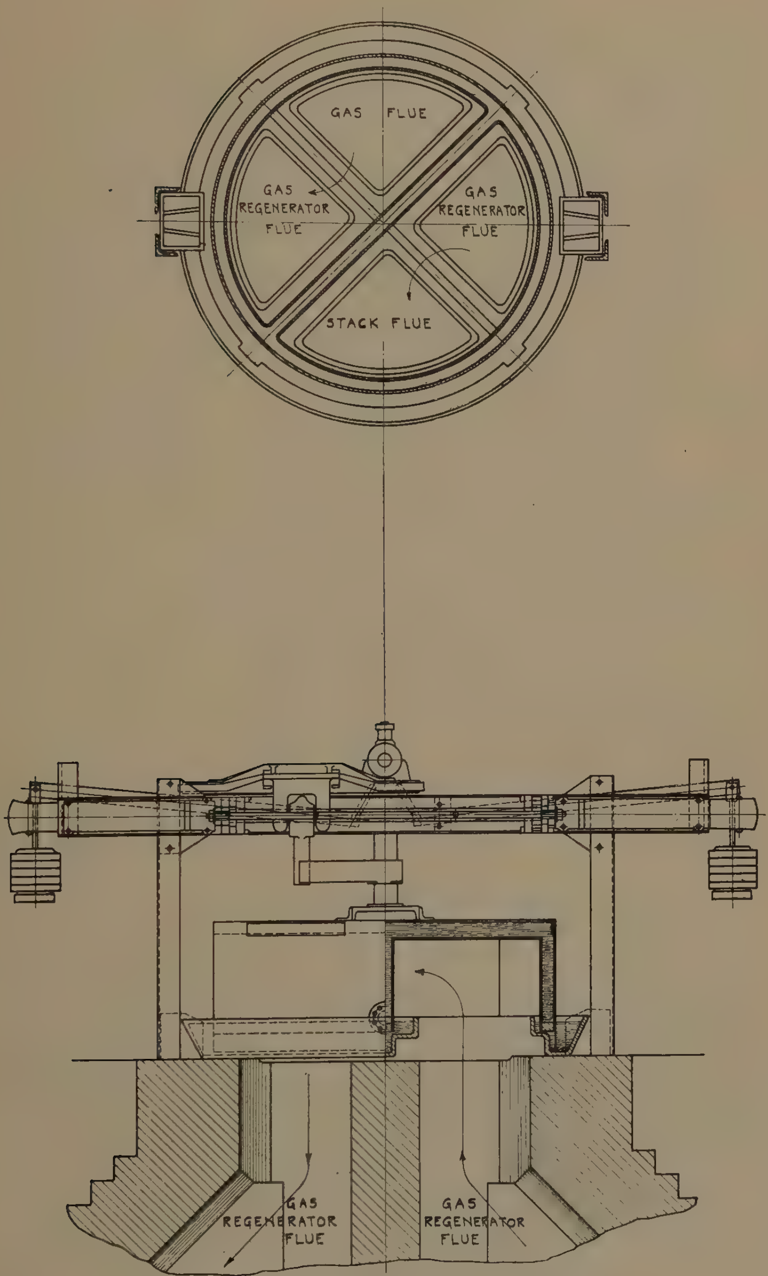


Fig. 21—The Dyblie gas reversing valve.

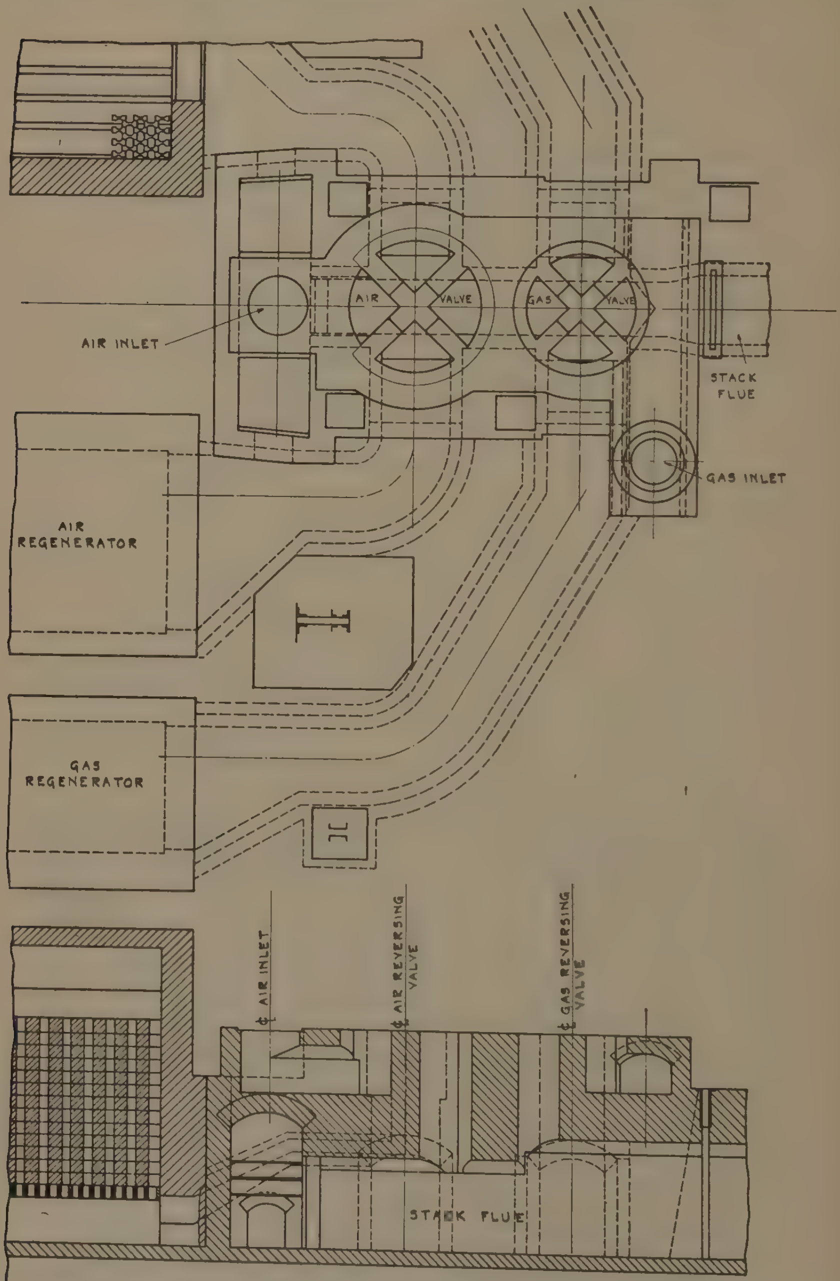


Fig. 22—Reversing valve and flue arrangement, South Works, Illinois Steel Company, 1905.

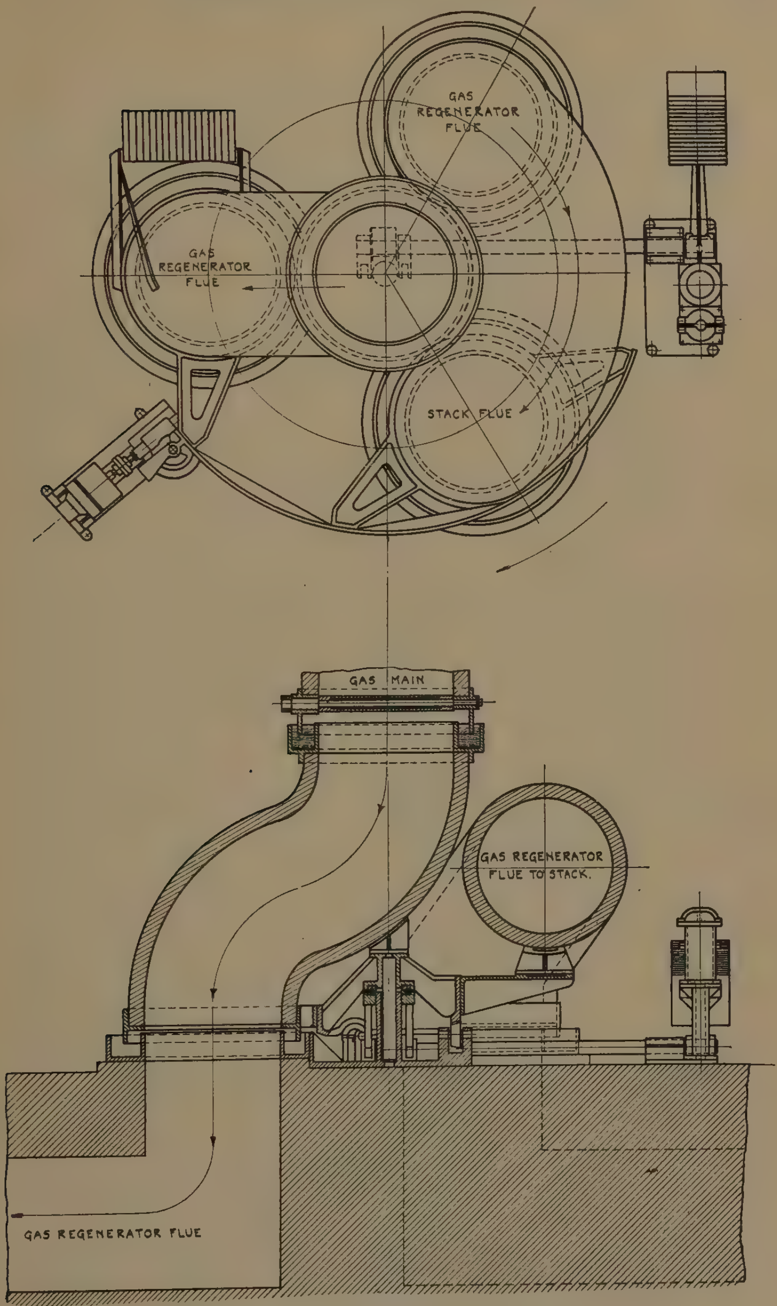


Fig. 23—The Modified Blair Valve.

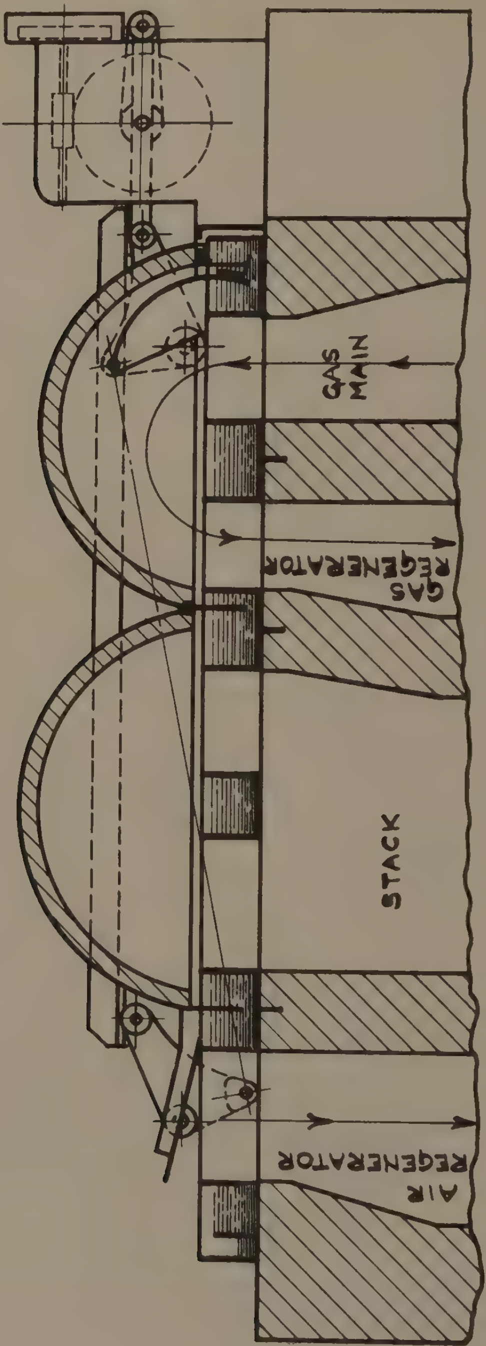


Fig. 24—The Isley Valve.

THE CHAIRMAN (Mr. William A. Rogers): Discussion of this paper by Mr. Francis L. Toy, Superintendent, Open-Hearth Department, Homestead Works, Carnegie Steel Company, Munhall, Pa., will now be presented.

Discussion by FRANCIS L. TOY

Superintendent, Open-Hearth Department, Homestead Works, Carnegie Steel Company, Munhall, Pa.

To exert a strict and rigid control over the open-hearth furnace is an ambition worthy of the best open-hearth men in our steel industry, for only as complete control of all the factors contributing to the open-hearth process is approached are the elements of speed, economy and quality of product most fully realized.

Mr. Bulmer has shown us that in the case of one set of extremely important apparatus, the air and gas valves on which we rely for a very large part of the control of the furnace and the process, there is a very serious deficiency as a real medium of control, for we cannot rest content with such a lack of efficiency in the very means by which we hope to regulate gas and air and products of combustion to give their maximum efficiency in other parts of the furnace. If we spill our efforts in the regulation, how can we get all that must be expected from ports or regenerators or liquid fuel burners, even if the best ever installed on a furnace? How many times in the past have new ideas applied to the fuel burning and regenerative equipment of a furnace been strangled and rendered ineffective because the valves and flues cut down the vital draft effect and helped lose heat units as fast as they were gained? Correct principles in design of ports and entry of fuel cannot give nearly all of the higher calorific effect that should be finally obtained or the better economies that our open-hearth establishments must in the long run show, if not backed up by simple and direct valve action, short and direct flue passages.

Mr. Bulmer's statement about draft loss by friction in the valves has been very well substantiated. The ratio of the effective draft in the flues on the regenerator side of the valve to the stack draft would show an even lower figure were the measurements at the stack taken on as low level as those in the flues. At Homestead we have found that for a furnace equipped with the double seated mushroom valve, as illustrated by his Fig. 7, experiments may show a draft depression of 1.4 inches of water at the stack at floor level, and a depression of 0.6 inches on the regenerator side of the valves. This for a furnace that could by no means be used as an example of a slow, sluggish furnace, but one that would compare favorably in speed with any in the country. From this one might foolishly fall into the error of assuming that large differences in draft depression from one side of the valve to the other count for little as affecting furnace speed. Better take the true lesson brought out, that most furnaces in the country could make better speed in proportion as resistance to flow between stack and regenerators is lowered.

Along with the question of frictional losses must be considered the effect of infiltration of cold air through leaks in valves and flues, which will inevitably destroy draft effect because of lowered stack temperature. Let us not forget that the stack or waste-heat boiler fan, acting universally on the principle that it will satisfy its draft by the easiest and quickest means, will emphasize any leaks that exist in the flues, valves, valve settings, dampers, stack base, etc., so that it is of the utmost importance to keep this whole system sealed permanently against air leaks, and in no case is this so vital as where the valve system already presents high resistance to gas flow. The unnecessary chilling effect noted above applies equally well in the case of leaking water seals, splashes of water from water seals on reversal, too large an exposure of water surface at the water seal, or in fact, any defect that introduces water into the flues, or construction that provides more than the water volume or flow strictly nec-

essary for upkeep of the valve. It certainly behooves us to make the very best use of water for cooling and to use a method that will allow for a minimum amount. The paper under discussion shows very well the tendencies of various valve types as to chilling effect on the passing gases.

It is well to try to bring out here that leaks through settings and through seats are particularly noticeable and hard to prevent in the case of valves operated by hydraulic pressure cylinders, particularly where the hydraulic pumping system is not ample in capacity and other hydraulic machinery is operated off the same pressure line. Thump and jar are undesirable and certainly to be avoided at reversals, but by the above undesirable condition in many hydraulic systems we get in addition an intermittent jarring action between reversals which loosens up valve settings and connections between valve parts, making almost impossible the maintenance of the sealing vitally necessary, besides an intermittent lifting of the valve which, although for only a small fraction of an inch, if frequently recurrent, will cause enough cold air leakage into the flues to very seriously effect stack draft.

Repetition of some of Mr. Bulmer's statements may give them the emphasis they deserve and I accordingly reassert the extreme importance of the continuance during the entire furnace run of proper distribution of the waste gases between the air and gas checkers. Disproportionate velocities of flow as between gas and air regenerator chambers will mean that one chamber will be clogged by dirt more rapidly than the other, the clogging reacting to further reduce the velocity of the gases and greatly accelerate the blocking of the one chamber relative to the other. Again, where one chamber fails to show proper temperature in heating and cooling relative to its companion on the same end, it is found that by restricting the flow from one chamber to the stack a much better temperature relation between the two can be had,

and this relation at best is the one that by trial gives the greatest contribution through net preheat to the flame temperature in the furnace.

Adoption of ports of improved design may demand a relation between gas and air velocities somewhat different from those usually obtained for a given gas and air regenerator volume and for given flue areas. To obtain the maximum effect from such ports without redesign and construction of the regenerator and flue system (bearing in mind also that good data for such redesign is most likely not at hand) demands a valve that can be readily and economically used to give the proportion of gas and air up to that showing in the furnace the highest and best calorific effect.

In order to contribute to the desirable effects of low frictional loss, proper proportioning of flow through checkers in both directions and, in fact, to gain most of the desirable features of furnace operation mentioned in the paper and its discussion, it is certainly evident that the valve must be first of all ample in area to prevent its choking by our means of regulation.

It is evident that most of our demands for simplicity, compactness, easy and continuous control, low friction loss, and for direct and simple flue arrangement are best satisfied by a vertical slide valve, provided the inherent tendency of this valve to warp and to leak air can be eliminated by mechanical construction. As ordinarily built and used it is almost impossible to keep them tight against air leakage through the guide slots. For example, at Homestead we have found that when the simple cast iron vertical slide valve is used as a stack damper the drop in stack temperature, due to leakage of air through the slot at the top of the valve, was as high as 200° F. The inclination of this valve from the vertical so as to give pressure against the seat, and the use of a hood with a stuffing box for the sealing of the valve stem, has eliminated the serious drawback of leakage, which, with the warping action associated with the dry slide, has kept this

valve from the development warranted by its inherently correct principle. I believe this type of valve can best satisfy our demand for a minimum water-cooling effect by its equipment with a closed water circulation, permitting the cutting down of the water volume per minute to a minimum consistent with mechanical upkeep and the elimination of large volumes of exposed sealing or cooling water. To date the slide valve as developed to its fullest extent seems to offer the best foundation on which to build new flue layouts or a means to simplify old installations to the end that many of the hampering, time-losing features of our furnace cellars, or "kitchens," or "downstairs" may be set aside for good.

A review of old installations will show actual and apparently unsuccessful trial of valves which, while embodying principles now accepted as "good" and illustrated on some of the modern valves widely heralded today, were not practical at the time from the standpoint of those using them, because the methods and materials of engineering were not such as to render the valves durable under operating conditions. In 1889 we find a vertical butterfly valve at Homestead with the valve plate water-cooled. Such an arrangement for a butterfly valve for air is now considered as a very great improvement over the old arrangement seen on many old furnaces and some rate it second only to a slide valve for this purpose (see Mr. Bulmer's Fig. 5). In 1900 we find a water-cooled slide valve at Worcester. Up-to-date methods of flanging plate steel and welding it would no doubt have lead to much further and successful use of these valves at the time. The lesson is that we should try to embody the simplest and best principles in our valves and strive earnestly to evolve them into durable mechanisms. Many of the cumbersome, inefficient, high-resistance valves are the result of a too ready compromise of correct principle to a construction that would eliminate mechanical faults irritating at the time, but not merely so important as was the germ of good principle that was latent in the valve.

I do not believe enough has been done to bring to the attention of melters and first helpers the extreme importance of regulating the air supply to the valves so as to get the maximum calorific effect from the fuel. The limited space in which the valves are usually placed has not only made for very bad flue arrangement with difficult angles and many turns, but has tended to make difficult the quick regulation of the air supply. In fact, the design of such regulating devices, as for instance the air mushroom valve controlling the admission of air to the valve or flue, is not, in many cases, one that places it within easy reach or makes its opening variable without considerable effort. Such device should be, with the means of control for the gas, so placed and operated that the first helper may easily accustom himself to the regulation of both elements of combustion and he should avail himself at all times of such regulation for the promotion of the maximum furnace speed and economy. The lack of such control of air supply will be particularly noticed in old open-hearth plants in shifting from one fuel to another and where considerable fluctuations in gas pressure take place.

For those who would accustom themselves to a theoretical consideration of gas velocities, valve and flue resistances, and influence of areas on the same, a careful following of the calculations shown by A. D. Williams in a series of five articles appearing in the *Iron Age* this year will prove a valuable aid in approaching the subject.

In Mr. Bulmer's paper I very earnestly recommend all of the statements covering the prime factors in good valve design and particularly his warning against the waste of useful stack or fan draft where this energy can be used to pull gases through regenerators having closer setting of brick with consequent larger heat retaining capacity, or through smaller and more efficient furnace ports.

We are all very much indebted to him for his clear presentation of the outstanding errors and difficulties and

his plain indication of the principles through which lie a brighter future for air and gas valves.

The Chairman (Mr. William A. Rogers): Are there others who wish to discuss this paper? The meeting then is adjourned. Our next gathering will be at 7 o'clock for the dinner.

EVENING SESSION

The evening session of the Institute was held in the Grand Ballroom of The Commodore. After dinner, President Gary called the meeting to order.

JUDGE GARY: Ladies and gentlemen, I ask you to drink to the President of the United States.

(The toast was responded to by all rising, the orchestra playing the Star Spangled Banner.)

JUDGE GARY: To the King of England.

(The toast was responded to by all rising, the orchestra playing God Save the King.)

JUDGE GARY: Ladies and gentlemen: nearly four years after the close of the greatest of all wars known in history, our minds turn back to some of the phases and some of the periods of that war which were most striking, were critical and depended almost upon the turn of the hand as to whether or not the defense against the tyrannous, the blood-thirsty and the well-prepared forces of the Central Powers should be defeated or be successful.

We remember particularly some of the events of the beginning and of the early days and months and years of that stupendous struggle. We remember how for several days we were almost terrorized by the thought as to whether or not England would come to the rescue, to the assistance and to the help of the French and Belgians, who were almost in the throes of despair; how finally the news was flashed across the wires that England had decided to cast her lot in favor of the preservation of civilization and the integrity of the weaker, or at least the more poorly prepared of the nations who had been ruthlessly attacked; and that promptly, without any unnecessary delay, all the English military forces which could be assembled would cross the Channel and enter

DINNER OF THE AMERICAN IRON AND STEEL INSTITUTE IN THE GRAND BALLROOM OF THE COMMODORE, NEW YORK, MAY 26, 1922

the military contest and that they would be led by a man who had long been chief of staff, who had fought through the wars in Africa, who was learned and skilful and who by his knowledge and his experience and his achievements was competent to direct a large military organization—that General French would be at the head of those forces. (Applause) And we followed his career day by day and month by month. We saw him at the very beginning when he was compelled, with troops inexperienced in battle, to a large extent, to occupy certain space and to defend against an army that had been preparing for years for just such a contest as had been commenced.

It is not a difficult matter for an organization, military or otherwise, thoroughly trained, to carry on a battle or a contest of any kind in the very best way and to the fullest extent of the power and capabilities of the implements and the facilities at hand. But to take a new army, a large one, not expecting war, not thoroughly prepared for battle, and however competent the leader is, to make the most of that army, to get the best out of it, requires not only courage and determination but the greatest skill and the greatest ability. (Applause)

We saw General French with his army protecting the space allotted to him, and although compelled by orders and by the situations to retreat day after day, and in order to do that to sacrifice his men only when and as necessary, we saw General French making that retreat, keeping his lines in proper place and protecting his territory until it was forced back to the Marne; and when the time came and General French, with his army augmented from time to time and with such equipment as could be furnished in the short time, listening, waiting for the command to advance, we saw him take up his offensive work and carry it on in co-operation with Joffre, with the utmost skill and ability, making for his soldiers a reputation which was equal to the best. And then we saw him from day to day under still more difficult situations when, particularly at Ypres, he was

compelled to fight two great battles, directing by that time a very large army, and he having become Field Marshal—I do not know on exactly what date, perhaps very much earlier, perhaps in the beginning of the war—we saw him directing and winning two of the greatest battles ever fought in any war or in any country. (Applause) On the 31st day of October and the 31st day of November, 1914, it was a question whether or not it was possible to prevent the German armies from crossing through that neck, through and beyond Ypres to the Channel, and if so, probably down the coast even to Havre, which meant the entrance to England, perhaps the destruction of England, perhaps the end of the war. Marshal French, with less than half the soldiers, including the Belgians and the French which had been turned over to his command, less than half the number which the Germans had in their army, and with perhaps less than half the artillery and with guns very much smaller in caliber than the Germans had, fighting day by day and night by night in defense of that line of battle—I wonder if we realize that this was the entrance to England itself? I wonder if we realize what odds Marshal French was compelled to meet. I wonder if we know that his men almost died of fatigue? I wonder if we can realize that part of the time he was nearly out of ammunition, and that many times during those great battles it was only the flank bayonet charges which he directed personally which saved the English Army from utter defeat? Any of you here who have seen Ypres since the war and knew that beautiful city before the war and are familiar with the ground in that vicinity can visualize what the slaughter, what the terrific battles of that locality were. And Marshal French, keeping his headquarters close to the battle front, going from Haig to Foch and from one general to another and keeping in close contact with that whole situation—I wonder if we can credit the man, who had the courage and the ability to manage a great army

under those circumstances, with what he is entitled to? (Applause.)

It was my good fortune to meet Marshal Earl French in New York in 1912. I was giving him a luncheon at which I had assembled some of the prominent men of New York. And while we were at the table the Marshal, who was then General French, said to me, "I have just received a cablegram from my country and I am ordered home immediately." I said, "I fear that means danger," and he said, "That is what I fear, and I must go at once." I want to say to you, ladies and gentlemen, that was really the beginning of the great war, and from the time the Marshal returned to England until the war broke out in 1914, he knew perhaps better than almost any other man that it really was the first symptom of the great war and that it was inevitable. And so, of course, he was the man who was best prepared from the English standpoint to lead the forces, and when he was selected by the Government to go to France, he said generously and naturally, "I should like to have Kitchener go as one of the leaders with me." (Applause.)

No wonder you cheer at the name of Kitchener, the man with whom General French fought in Africa. But Kitchener replied, "No, French, you must go. You are better able and better prepared than I am to do that work. I will stand by you," And French went and Kitchener was made Minister of War. (Applause.)

Now after these long years and in these great times of anxiety, we can only look back over those scenes with a feeling of gratitude that French happened to be alive, that he was in England and that he was put in command of the English forces and that we have the very great honor of having with us tonight that great man, Field Marshal the Right Honorable the Earl French of Ypres. Hear him. (Prolonged Applause.)

Field Marshall French: Judge Gary, ladies and gentlemen: I really can not find words adequately to express what I feel in the great honor you have done me

in asking me to be present at this most distinguished gathering tonight. And I appreciate your kindness still more because of the fact that I am visiting your country simply as an ordinary private citizen of Great Britain. (Applause.)

I was met at the steamer by many representatives of the Press of New York. I was received by them with the very greatest kindness and the warmest welcome, which lasted for some two hours during our entering into New York. They certainly tried to force me at the pencil's point to admit that I was coming here on some mission or some other, as they said, "stunt." Well I do not know, gentlemen, whether taking a holiday is another name or has a meaning in the word "stunt" or whether it is what my friend Mr. Winston Churchill (applause) would call or term a logical inexactitude. But however that may be, I give you my word that that was the only "stunt" I was on, and certainly I think perhaps after more than fifty years of continual service for my country, I have perhaps a right to indulge in such a "stunt." (Applause.) Whether I had any other idea in coming to this country I do not know. Subconsciously I may possibly have had, because for some months I have been idle, and I have been told somewhere or other that idleness is the root of all evil, and I remember that old writing of Dr. Watts, who said that "Satan finds mischief still for idle hands to do." I may have been influenced by that, and therefore have thought it was a good thing to come to a country so solicitous for the welfare of all we weaker brethren as to change its Constitution the eighteenth time in order to lead us to salvation. (Laughter and applause.) Whether this was on my mind or not I do not know, but at any rate it gave me the very deepest pleasure to come and I am very, very glad to find myself here.

Judge Gary, you have referred in the most kind way and with noble and generous words to the work which I and my comrades were able to do for our country, and for all the Allies, I hope, also, at the commencement of the

war. I can assure you, gentlemen, the estimate of our work which is evidenced by your words and by the manner in which you received Judge Gary's speech is the most welcome tribute we could possibly have, coming from that wonderful body of the Steel Corporation of the United States. It adds precious laurels to our standards, and above all and before all it lays another immortal wreath of glory on the graves of our dead comrades.

You have referred, Judge Gary, to the time when I met you here and when I received such kindness from you and Mrs. Gary in 1912. It is curious that you should have been associated with me on two such important days, one of which you have mentioned; the other was in Paris on the 14th of August, 1914. I was on my way to the front. I had come officially to Paris and I was sitting with Lord Bertie, the late British Ambassador. There was a great deal of business going on at the embassy and I suggested to Lord Bertie that I and my party should go and dine at the Ritz without disturbing him, which we did. I am sure many of you know the Ritz of Paris, and you know the appearance the dining room generally presents about half past eight or nine in the evening. Imagine that great room with only four people in it, Judge and Mrs. Gary, myself and my aide-de-camp.

Well, he will agree with me, I think, in what I am going to say to you as regards the attitude of the French people. They received me with the utmost enthusiasm and kindness. I drove all the way from the Gare du Nord to the embassy amidst crowds and crowds of people. But their attitude was what struck me so strongly. It was an attitude, which you saw in every face, of grim determination. There was no sort of arrogance, no kind of idea that they were going to have a walk-over, or the spirit which manifested itself so strongly in them in 1870. There was none of that at all. They had made up their minds that they had a grim, terrible struggle before them, but that they were going to win. And I believe it was that spirit which made them win at last. I am

sure Judge Gary will agree with me that those observations were his as well as mine.

Well, so it went on. Judge Gary has told you of that little, contemptible army which I had the honor to command. And I should like to say just a few words to you about that army. A great military critic—it sounds egotistical of me to talk like this perhaps, but I do not mean it to be so—a great military critic said of it that it was the best army of its kind and for its size that had ever taken the field. Well, now, gentlemen, considering all they did, because after all it was they, not I, that did the work, I think they were not words of extravagance. It was composed of veterans. Its discipline was perfect. And after all you must remember that discipline is the keystone of all military efficiency. (Applause.) The very best spirit permeated through its ranks. But above all, its organization was as perfect as I think anything can be in this imperfect world. The question of organization is a very difficult one. You cannot really organize an army in peace time. Remember, I am talking of peace time because you can do a great deal in war time that you can not do in peace. In peace time you cannot do much in a few months, but it is a question of years of trial and struggle, and I do not think that anyone in that army, in high command at any rate, ever doubted that its efficiency was largely due to the creative genius of that great statesman who was Secretary of State for War between 1906 and 1912, Mr., now Lord, Haldane. Unfortunately the great work of great men is very often overlooked and in the dash of arms peace labors are very often forgotten. But no man can possibly take away that credit from Lord Haldane which belongs to him, of having that army ready to strike when it was wanted. Through those years I was one of his military counsellors and also part of the time chief of the general staff, so I really know what I am talking about.

I suppose that history will get a very much better perspective of everything connected with this war

than is possible for the present generation; but when that classic story, that great classic story comes to be written, I think the very foremost place, a very great place, will be assigned to that great Army of the United States and to its Navy, which did so much. It is a matter of great regret to me that the fortunes of war did not allow me to stand beside them in the field, but I had the great privilege of knowing intimately some of its chiefs and I heard from my own comrades, at first hand, of the splendid work which they were doing. Your wonderful transport of that army over 3,000 miles of sea in the face of submarines and aeroplanes certainly excited the admiration and wonderment of the whole world. And then came that splendid record of fighting which you maintained from beginning to end and your splendid participation in that mighty victory which brought liberty and freedom to the world.

Gentlemen, I do not know why it is, but you Americans always seem to me to repudiate the idea of being a military nation, but God Almighty made you great fighters, made you great soldiers, and you cannot help it, you cannot get out of it. That is just exactly what you are. I suppose your history as a nation does not extend over a great number of years when we consider the history of old nations, but you have somehow or other crammed it full of fighting and you have always fought splendidly and you have always succeeded. Why, you are not a weak nation. Take your Civil War. I myself have been a most earnest student of your Civil War all my life. The combats, the battles and the campaigns which composed that war are great military classics. They are studied and read in every military college and university in the world. Their deeds and their decisions and the conditions under which they won battles are what the lawyers call precedents for all time. On them great rules of strategy have been founded upon which strategists and tactitians found their ideas. Then take all the great leaders on each side—Grant, Sherman, Sheridan,

Stonewall Jackson, Lee—everybody, take them all, they are household words in the mouth of every soldier that knows anything about his business. Then you say you are not a great military nation. I say you are; I think you are one of the greatest military nations in the world and you always will be.

Well, gentlemen, may I say just one word, as our meeting today is graced by the presence of ladies. I never lose an opportunity when ladies are present at such gatherings as this to express the gratitude, the profound gratitude which we all feel for the great work which was done by what I will call our women, in the war. (Applause.) We saw young girls employed in factories at ammunition work with faces beaming with delight, carrying weights about, doing the work of great, strong men. We saw them in the hospitals, we saw them at the front, we saw them sitting up night and day and wearing out their health in making comforts for the men at the front. We saw them doing everything, and I am quite sure that when the history of this great war comes to be written, its most brilliant pages will be filled with their work. (Applause.)

I have traveled over a great deal of ground, I am afraid, gentlemen, and I have spoken on a variety of subjects, and fear you must agree with me I have been a little disconnected in my remarks. I hope you will remember that I am neither an orator nor a statesman, but only a simple soldier whose life work has been not in the council chamber, but in the field. In such an assembly as this, which I know is full of orators, I feel my deficiencies very, very keenly in speaking to you. But I am quite sure I shall be safe if I throw myself on your generosity. I have perhaps wearied you, and I fear I have spoken too long, but I cannot help before I sit down just saying one word more about this great field organization.

The association of the soldier and field is as old as the history of war itself, and in my humble opinion it will last as long as war lasts. There are people who

would have us believe that military operations of the future are going to be the exclusive affair of chemists and aeroplane engineers. I do not share that view at all myself. Infantry is, and always has been, Queen of Battles, just as I believe it is said that Steel is the King of the Industries. If I may venture a prediction, it is that it will be long before either is dethroned. A few years ago I remember reading in some magazine, it was some time before the war, an article on the operations of the United States Steel Corporation. The statistics which were quoted were so stupendous that they almost made one's brain reel. It was doubtless a very brilliant and informative article, but with great respect to the author, I am bound to say that it failed to make me realize then, as I was to realize subsequently, the vast power of the great commercial organization over which Judge Gary presides with such consummate ability. (Applause.)

Gentlemen, I am glad and proud to be your guest tonight and to have the opportunity of expressing my personal gratitude to the officers of the Corporation and of testifying to my deep sense of the value of the work which they did for the Allied cause in the war.

In conclusion, I should like to add that, judging from my own experiences and observation since I have been in this country, I should think the late Mr. Pierpont Morgan was fully justified in saying he would be very sorry for anyone who undertook to "bear" the United States. (Applause.)

Judge Gary: I think Earl French almost gave the United States Steel Corporation credit for having all of you within its family. (Laughter.) Well, I may say that we would be very proud if that were true, provided it were legal. (Laughter.) But I will say, notwithstanding the great size of the United States Steel Corporation, there are a great many other large, rich and prosperous steel corporations. And I will add that I am proud of being and having been since its organization the President of the American and Canadian Iron and Steel Insti-

tute, which embraces all of you, and that we are thereby one family and one unit. During the war we together furnished so much steel to our Government for its military purposes and others that every requirement that was made upon us was fully met.

Now, ladies and gentlemen, I want to say that we have two more speeches, not long, but in which you will be interested, from men whom I will name, without giving these gentlemen any previous notice or opportunity to prepare, but who can always be depended upon to say something that will be interesting and of benefit.

I will first introduce Mr. John S. Unger, Research Engineer of the Carnegie Steel Company. Mr. Unger, will you come around here. (Applause.)

MR. UNGER: Mr. President, ladies and gentlemen: As our chairman has so truthfully said, I have not had one instant for preparation. However, I have but a few minutes to talk to you and I want to make it just as short as I possibly can. I am going to take a prophet's license this evening. You are all familiar with the fact that it has been said long years ago that a prophet is not without honor save in his own country, and in his own household. I am going to take a glance into the future, an unbridled license, so to speak, and point out what the members of the American Iron and Steel Institute may expect within the next decade, or perhaps within the next quarter of a century.

Take the modern 100-foot blast furnace, with 4 stoves of equal size using 40,000 cubic feet of air to make 750 pounds of pig iron in a minute. When oxygen has been reduced to $10.00 per ton, the air volume of 40,000 cubic feet will shrink to 8,000 cubic feet of oxygen; the stoves will disappear altogether, as the oxygen will not need preheating, while the furnace will not be over 25 feet high, from which a continuous stream of iron will be running from the tapping hole and a similar stream of slag from the cinder notch.

The transportation of our iron ore has materially

changed in the last 35 years. The early railroad car which was unloaded by shoveling over the side gave way to the drop bottom, then to the hopper bottom, but by far the quickest and cheapest way was to turn the car upside down, unloading twenty-five 50-ton cars in 60 minutes. The Lake ore boat requires 6 or more hours to unload 10,000 tons, a wonderful performance according to our present lights, but to my mind old-fashioned, antiquated stuff. (Laughter.) It should be run into a basin, strapped down tight, then turned over and shaken, put back into the water with orders to return for another cargo, and all within the space of 30 minutes.

We use at one of our by-product coke plants about 12,500 tons of coal daily. To move this coal and that required for steam and fuel purposes from the mines requires mine railways, tipples, a fleet of steamboats and barges and coal elevating machines. Coal has been pumped as a sludge 25 years ago. Our coal should be crushed at the mines, dumped into a steel tube 8 feet in diameter, mixed with enough water to make an easy-flowing sludge or mud of coal, then forced by centrifugal pumps to a large settling basin where the water is drained off, and the coal is ready for use. This method of conveying coal is very cheap, not affected by high or low water, a frozen river or labor strikes during its transportation.

Tubular steel products such as gas bottles, gas tanks, torpedo tubes or large seamless products are made by a hot cupping and drawing process or by centrifugally casting. Articles of equal size made of glass are blown. Glass lends itself readily to this method of shaping, as it is plastic over a long range of temperature. Blown steel products should be produced with equal ease, but as the viscosity of hot steel is less and does not cover the temperature range of glass, the operation must necessarily be performed in a heated chamber, kept at such temperature as will preserve the viscosity. When this has been accomplished, the process of cupping and drawing and

that of centrifugally casting cylindrical products will be discarded.

We use large slabbing, blooming and cogging mills or hydraulic presses to roll or forge the large ingots to near the finished size of the piece to be made. Many believe that an improvement in quality is produced by plenty of work between the rolls. When an ingot has been reduced to one-half of the original area, very little additional improvement can be made by any greater reduction. Small sections, as wire or bands which have had a reduction of 1000 to 1, are superior only in so far as the more rapid cooling of the small section has affected the structure of the steel, which changes the physical properties. European practices, particularly French and German, lean toward small ingots, thereby doing away with the roughing mills.

In the '50s of the last century, Henry Bessemer and others, experimented by casting the section close to the final size direct from the liquid steel, between water-cooled rolls. While it was still hot, it was given a few passes in the rolls to reduce it to the exact size. Very intricate sections can be cheaply made in this manner as proven by work done with copper, aluminum, lead and tin. This method will be revived and developed for steel with the consequent abolition of the roughing mill.

In spite of our interest in iron, it is not an ideal metal. It is cheap, can be obtained in soft, medium, and hard varieties for the many purposes for which it is used, but it is too heavy and rusts rapidly, both of which are important objections. Much has been done to resist corrosion by alloying with other elements. We now have stainless, flameless, invar and copper-bearing steels, but with the exception of the last they are too expensive. In less than 25 years iron will be rendered partly or wholly rust-resisting by treatment.

Seventy-five per cent of all steel made is under 90,000 pounds tensile strength per square inch. This will be replaced by an alloy of iron, aluminum and silicon, re-

DINNER OF THE AMERICAN IRON AND STEEL INSTITUTE IN THE GRAND BALLROOM OF THE COMMODORE, NEW YORK, MAY 26, 1922

duced electrically from common loam or clay. This alloy will weigh about one-half that of iron and will rust very slowly. It will cost more than structural steel, but as it will not require protection by coating and will last indefinitely, it will be cheaper in the end.

The United States has a population of 110,000,000, and produced, during 1920, 42,000,000 tons of steel or at the annual rate of 855 pounds for each inhabitant. The population of the world is about 1,500,000,000. When steel is more universally used by the Oriental countries, it will require the production of more than 500,000 tons of steel every 24 hours to supply the demand. (Laughter.) This enormous consumption will soon exhaust the rich iron ore beds of Central Europe, Norway, Russia, China, India, the United States, Cuba and Chile. Beds of iron ore now considered entirely too poor to be worked will be worked before the middle of this century. I firmly believe the metal of the future, perhaps 25 years hence, will be an alloy of aluminum, silicon and iron obtained from common clay or loam.

The United States can produce 50,000,000 tons of steel annually, but cannot use this amount. This means that we must find a market for our surplus steel or find new uses for steel. It means that each and every man in this audience tonight, who is engaged in the steel business, must study the situation and find new uses for steel. We should use steel furniture in our houses. This table and these chairs should be of steel. Our goods should be shipped in collapsible steel packing boxes which cannot be used for fuel at the end of their journey, but may be used many times for what they were intended. We should use a steel railroad tie, seamless tapered steel telephone and telegraph poles, a light, cheap knock-down steel barrel, not necessarily liquid tight, but capable of carrying flour, sugar, or other materials not requiring a liquid-tight container.

You can all remember when the first steel railroad car came along. You rather ridiculed it and said it will not

work, it won't do. But as a matter of fact nothing but the steel car would stand the service that is demanded of it today. The modern skyscraper, the Hell Gate Bridge, the ocean steamship, could not exist except for steel.

In conclusion, I want to repeat a few lines:

> Strange things will be done
> Through the years as they run
> By the men who make our steel.
> Through the prophet's sight
> We can see the light
> That the future will reveal.
> When we turn and look back
> O'er the long, long track
> Of the years through which we passed,
> We can say as we view
> Things did appear new,
> They're old now, we fear they wont last.

I thank you. (Applause.)

JUDGE GARY: I have the pleasure of introducing one more speaker who has not had any previous notice and who has kindly consented, as a favor to us, to speak briefly. I will introduce Mr. Willis F. McCook, of Pittsburgh, President of the Pittsburgh Steel Company. (Applause.)

MR. MCCOOK: Mr. Chairman and gentlemen: There is a certain parallelism in Judge Gary's life and mine. I recall with great pleasure in the early part of my career being associated with him in the legal profession as representing various steel interests. He and I have been in the steel business all our lives except that in one period of our lives we changed the spelling of the word. (Laughter and applause.) The same thought was expressed by one of the metropolitan journals here in New York in relation to our legislature at Harrisburg, when it referred to it as the "Pennsylvania Steal Works at Harrisburg."

I was impressed this morning with the various political suggestions in Judge Gary's address. I do not think it proper to introduce politics in such a meeting as this. I feel like the Irish priest who was hearing the confession of a Sinn Feiner, and he says, "Father, I killed a Black-and-Tan last week." "Ah," he says, "my child, keep politics out of the confessional and tell your sins." (Laughter.) I will keep politics out of my speech, but I will not tell my sins.

The thought I got from Judge Gary this morning was the important fact of legislation being passed affecting your interests and mine by classes. Mr. Bryce, in his "American Commonwealth," speaks of the peril of the American Democracy lying in that very fact: that organized classes will secure control of legislation and enact legislation solely in their own interests. And this danger to our country becomes more probable from its very extent. It is so wide, it is so large, it extends from the north on the Canadian line down through hundreds of miles flow of the Mississippi River as she goes unvexed into the Gulf of Mexico, and from the Atlantic to the Pacific. It is no wonder that we have varying interests from this great extent of our country and that at times those interests are in conflict with each other. We had an expression of it in the early days of Pennsylvania in the Whiskey Rebellion, when we objected to our whiskey being taxed, and we had the Whiskey Rebellion located in Pittsburgh. We had another expression of it which never could have been heard of were it not for these factors, in Burr's Rebellion. We had a still greater expression of it in the Civil War of '61.

The danger of Democracy, or rather the danger to Democracy, in our country is so great from these causes that the suggestion made by Judge Gary this morning is pregnant with thought.

I wish to refer to more recent things as illustrating this terror. Does any man believe that the Adamson Law was passed by the approval of the majority of our

people or of our legislators? Not at all. It was forced through by an organized class standing in the gallery of Congress and holding their watches on our congressmen. And the evils that have grown out of that piece of legislation we are not done with yet. Mr. Bryce speaks of a democracy as a country ruled by a majority, decisions reached, laws enacted, which have been considered and approved of by a majority of our people. Did the majority of our people or of our legislators really approve of the Adamson Law?

Take a more recent case, of the Volstead Law. Will any man pretend that that enactment was passed by the will of the majority of our people? And if it were not, then we are not acting as a democracy. The soldiers' bonus legislation will probably be carried through by the same organized minority; and if it is, it is not a democratic measure. And we have had an expression here in the last election in various portions of our country of another organization, secretive and concealing even the personalities under a garb. I refer to the Ku Klux Klan. Now, we cannot as American citizens permit this thing to go on, if we have due regard for the safety of our country. If this is to be a democracy, let us see that one class shall not be arraigned against another, nor against all others. I say that a man is guilty of treason to his country, treason to her best interest, treason to the general welfare, who will seek to array one class of our citizens against another, I do not care whether it be organized labor, I do not care whether it be a racial organization with the black against the white, I do not care whether it be religion of one belief against another, it is treasonable to the general good.

Now, these thoughts came to me this morning as Judge Gary read his admirable address. You see it in the tariff, where one class is trying to secure legislation for its interests against the general interests. This is an evil, gentlemen, that is growing. We have the Farmers' Bloc, another example of it, threatening legislation that is not

for the general welfare. In an assemblage like this of stalwart men, men who think for themselves, men who have courage to act and speak, I think it is an opportunity which comes to me in the sense of a duty to ask you to set your faces against any such further legislation.

I do not know where the evil is unless it be right amongst ourselves. Perhaps it would be mitigated if we would reduce the number of our legislators, because with the great number we have in Congress, especially in the lower house, few men outside of the committee to whom the subject is committed really understand the subject. You take the tariff legislation now pending, with the thousands of articles on that list and a duty determined for or against that commodity in committee, it is absolutely impossible for the majority of the members of the House to go through that tremendous list and appreciate why a certain article should or should not have a protective duty.

Judge Gary said the legislation we have today on that subject, and always have had, is not considered; it is not fully considered. It should be in the form of a tariff body examining as to each article and reporting to a superior power. I have sometimes thought that the discretionary power which it is proposed to give to the Executive in the matter of tariff is better than the system we now have. In Canada they have a commission who can raise or lower a tariff upon their examination and consideration at any time. Certain discretionary powers are given to them. But if we want to be safe, if we want our country to prosper, if we want to readjust our affairs, if we want to get down to that which is best and safest, we must get away from this practice of class legislation.

Gentlemen, I thank you for your attention. I feel earnestly in this matter, and I hope every man will agree with Mr. Bryce, in his "American Commonwealth," that the danger to our country comes from organized class legislation. (Applause.)

Judge Gary: With expressions of admiration to the gentlemen who prepared the able addresses which were read before the Convention this morning, with thanks to all of you for being here this evening, and with sentiments of everlasting gratitude to the distinguished soldier who has honored us with his presence, and given us an able and friendly address, I bid you good-night. (Applause.)

OCTOBER MEETING

NEW YORK CITY

OCTOBER 27, 1922

AMERICAN IRON AND STEEL INSTITUTE

TWENTY-SECOND GENERAL MEETING

New York, October 27, 1922

The Twenty-Second General Meeting of the American Iron and Steel Institute was held at the Hotel Commodore, New York City, on Friday, October 27, 1922.

Following the usual custom, three sessions were held. In order to provide sufficient accommodations for the large number present, the morning session was held in the Grand Ballroom. The afternoon session was held in the East Ballroom. The evening session which included the semi-annual dinner, was held in the Grand Ballroom. The sessions were devoted to the reading and discussion of papers dealing chiefly with problems of metallurgy and business.

On the following page will be found the program ot the meeting. Judge Gary, President of the Institute, presided at the morning session. Mr. John A. Topping, Vice-President, presided during the afternoon session. Judge Gary acted as toastmaster at the banquet in the evening.

PROGRAM—OCTOBER MEETING

FORENOON SESSION

Address of the President.......................... Elbert H. Gary
Chairman, United States Steel Corporation, New York

Modern Methods of Mining Coal.......................... H. Foster Bain
Director, Bureau of Mines, Washington, D. C.

The Storage of Bituminous Coal.......................... H. H. Stoek
Professor of Mining Engineering, University of Illinois, Urbana, Ill.

And.......................... J. V. Freeman
Director, Coal and Coke Research Laboratory, United States Steel Corporation, Joliet, Ill.

Present Status of the Electric Furnace in Refining Iron and Steel.......................... John A. Mathews
President, Crucible Steel Company of America, New York

The Economic Importance of the Power Plant in the Steel Industry.......................... E. F. Entwisle
Assistant General Manager, Steelton Plant, Bethlehem Steel Company, Steelton, Pa.

Discussion.......................... F. L. Collins
Assistant Electrical Engineer, Gary Works, Illinois Steel Co., Gary, Ind.

AFTERNOON SESSION

The Steel Requirements of the Automotive Industry...... Henry Chandler
Metallurgist, C. H. Wills & Company, Marysville, Mich.

Heating Furnaces for Blooms, Slabs and Billets........ W. P. Chandler, Jr.
Fuel and Experimental Engineer, Carnegie Steel Co., Duquesne, Pa.

Discussion.......................... Willibald Trinks
Professor of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

Discussion.......................... W. B. Chapman
President, Chapman Engineering Company, Mt. Vernon, Ohio

The Use of Liquid Fuel in Metallurgical Furnaces.............. R. C. Helm
Director, Physical Laboratory, American Steel and Wire Company, Worcester, Mass.

Discussion.......................... J. A. Larocca
Combustion Engineer, The Texas Company, New York

The Thermal Efficiency and Heat Balance of an Open-Hearth Furnace.......................... C. L. Kinney, Jr.
Superintendent No. 1 Open-Hearth Department, South Works, Illinois Steel Company.

And.......................... G. R. McDermott
Assistant Chief Engineer, South Works, Illinois Steel Company, South Chicago, Ill.

Discussion.......................... S. S. Ball
Bethlehem Steel Corporation, Bethlehem, Pa.

Discussion (by correspondence).......................... Francis L. Toy
Superintendent, Open-Hearth Department, Homestead Works, Carnegie Steel Company, Munhall, Pa.

Fluorspar and Its Uses.......................... G. H. Jones
President, Hillside Fluor Spar Mines, Chicago, Ill.

EVENING SESSION

Impromptu Remarks in Response to Call of the President.

ADDRESS OF THE PRESIDENT

Elbert H. Gary

Chairman, United States Steel Corporation, New York

Gentlemen, you perhaps have noticed that arrangements or devices have been installed for carrying the voice in this room, and it is hoped that it will be beneficial in assisting those in the rear of the room to hear all that is said; but remember that as the voice of the speaker is carried farther and heard more distinctly, the same applies also to those who make any noises in any part of the room. Therefore, I am asking you to be very quiet; if you whisper, do it so that no one except your nearest neighbor may hear.

The program for today is pretty long and I think taken as a whole will be considered very good. The worst part of it is at the beginning. I hope the best part of it will be very near the last, if not the last part of the program, because that will consist of a few impromptu remarks by our own and only Charlie Schwab. I do not do any injustice by announcing this now, for it has been such a common practice and his efforts have been so well received that everyone now expects him to speak at about the end of the program; and he himself has almost become persuaded that he could not get out of it if he tried.

What I am going to read today I wrote about two weeks ago; to be exact I wrote it between twelve o'clock in the night and three o'clock in the morning. I sometimes wake up in the middle of the night; I hope none other has such a bad habit. But instead of trying to force myself to sleep I generally take up some subject for consideration and think it out, and the first thing I

know I do not know anything, because I fall asleep in that way. It is a good remedy for sleeplessness. This was a week ago last Sunday. It is a little dangerous to write a speech ahead of the time it is going to be delivered, because if anyone is desirous of being interested and of interesting others he takes up for consideration some theme, some topic, relating to current events, and if he says anything about current topics he is liable to be anticipated perhaps more than once before the address is delivered. And in respect to my speech, if it may be called that, I find by the papers this morning that Mr. Grace only yesterday referred to one of the topics, and I also noticed a few days ago that Mr. Hoover referred to another. Either one could speak concerning them a good deal better than I.

I think I should say that there is no report ready concerning the twelve-hour day question. I very much regret our inability to make more rapid progress. I am going to urge all of those who are particularly interested in this subject to furnish to the committee and the special subcommittees, at the very earliest moment, all the information that has been asked for. Quite a large number have neglected to do this. It is very necessary, very important, it is one of the biggest questions we have ever had under consideration. The President of the United States has urgently requested us to take action in regard to this matter and to secure uniformity of opinion and recommendation if possible; he is very earnest, very fair, very reasonable and conscientious about it. And in view of the heavy burdens he is carrying and the work he is doing for the country, I think we ought to do everything we can to assist him in anything he undertakes.

It gives me great pleasure, gentlemen, to again welcome you to one of these meetings. The room is filled. If it were a very much larger room it would be filled. As I came in rather early today, I was informed over thirteen hundred had already registered for today's

meeting. This is another demonstration of the popularity of the American Iron and Steel Institute. And there are many reasons. In the first place it is a good time for the iron and steel people to get together for the discussion of any and all questions which pertain to their business affairs and to the country, the national affairs as applied to our business. And then it is a time and place for learning a good many things that are worth knowing. The earnestness and the ability shown by members of the Institute who are selected to prepare addresses for these occasions are of the highest quality and most commendable; and these papers are of very great value to all of us. Of course you have an opportunity to read them after they are in print and everyone of us ought to read them at least once after they are published in our yearly book; but here is given an opportunity to see these men who prepare the papers and to hear them deliver their addresses. And those who speak are our creditors; we are their debtors. They are doing something for themselves that is worth while on their part in preparing these addresses and worth while on our part in listening to them and reading them.

Supply and Demand

What is to be said on this occasion relates to economics; and it will be spoken from the standpoint of the public interest. Our business life is represented by various groups of men and women and involves a great diversity of economic activities. Taken alone, each branch of industry is naturally selfish and influenced more or less by unworthy motives. In discussing any particular one, all others must be considered as a part of the general public. If in management any wrong or injustice is perpetrated, it is the general public which must finally in some way suffer the consequences.

Therefore in the consideration of all economic questions, every one should endeavor to determine the final

effect upon the people as a whole. Personal or private gain or advancement or political advantage must be subordinated to the general public good.

As industry has developed, populations multiplied and wealth increased, the problems and difficulties in economic life have grown and we have been correspondingly forced to concentrate our minds upon proposed measures for relief or protection against imposition.

And the greatest of all wars has very much complicated the situation, even in this country. Our recent industrial strife, the present pending agitation for the creation of an organization of classes calculated to secure power and benefit by physical force under the leadership of vicious men, with which you are more or less familiar, the profiteering that still exists, if in a lesser degree than formerly, are temporary relapses, so to speak, of the war fever, during a prolonged period of convalescence.

We are still suffering from the very high cost of living caused by the despicable cycle, developed during the war, which carries high prices from a starting point in a given place, proceeds around a spiral and returns step by step to a higher basis. Speaking generally and yet making the illustration specific, labor, which constitutes eighty-five per cent of the cost of production, is paid very large rates, but, with exceptions, is not paid more than is proper, because compelled to pay high prices for the living costs. Normal conditions have not been fully restored and apparently are not likely to be in the immediate future, unless extraordinary efforts shall be made.

We are apt to conclude that everything objectionable can be overcome by the adoption, amendment or repeal of laws. But on reflection one possessed with average intelligence and information, knows this is a fallacy. Many laws have been passed which are improper, and no doubt new ones ought to be enacted, all bearing upon economic questions. This will always be the case.

It is the purpose at this time to refer briefly to certain old and fundamental principles, which in modern times have been by large numbers overlooked or at least underestimated. Reference is made to the law of supply and demand.

This law is inexorable. It is like the mills of the gods. It may be slow but its work is sure and fine. In its application, it is technically the doctrine expressed by the old and well-known phrase "*quid pro quo.*" Individuals, groups, populations, become habituated to the idea that it is possible and also justifiable to get something for nothing; to get it by flattery, by mere promise, or by main strength and physical force.

But it might as well be admitted first as last by every individual, collection of persons, or nation, that in order to obtain what is desired, there must be rendered an equivalent value, and that if secured on any other basis the business will not be satisfactory. What amounts to an equivalent or fair consideration in any transaction is, of course, mutually determined by the parties concerned, and if each agrees freely and voluntarily with full knowledge of the facts, uninfluenced by coercion, action is and should be final.

If one seeks to acquire property of any kind, or service, a fair price must be paid; or if service demands a certain price, the fair equivalent in work should be rendered. Any attempt to bring about rules of conduct contrary to these fundamental principles will not be successful. If put in practice by force or fraud they will eventually fail. There must be standards that are just and logical, as between the parties connected, and not inimical to the public weal.

When an individual or association of individuals can and does collect an unconscionable amount for a commodity or for work, as the result of any circumstance or combination, the general public must and does finally pay the bill. This is inevitable and it is a pity that large portions of the public overlook or ignore this fact.

It is not difficult nor embarrassing for a man in business to increase the production cost of what he sells by additions in salaries or wage rates if, at the same time, he correspondingly increases selling prices.

What is to be done to prevent a practice which increases prices or costs from a starting point around or across back to the start and again commences another advancement? The first thing for every one of us to do is to think. One of our most prominent and ablest editors not infrequently urges us with emphasis to *think*, earnestly, seriously and all the time. We must adopt and practice the suggestion.

When we ponder over the situation with the idea of suggesting a remedy, the first question presented relates to combinations or conspiracies to suppress natural laws. If one is actuated by motives of cupidity or dishonesty, one is apt to suppress and then oppress. A combination calculated to control business or production either as to quantities or prices, by the employers or by the employees, interferes with the natural course of business and results in hardship upon all who are outside of the combination, who may be termed the consumers. A moment's reflection will bring conviction that it is because of these conditions, legislation has been invoked with the ostensible purpose of protecting the public, though it must be admitted that sometimes the real motives have been quite contrary to this idea.

But in this connection another question is presented, namely, how are we to distinguish meritorious from vicious legislation, presumably intended to prevent oppression? Any statute that unnecessarily interferes with the natural law of supply and demand works incalculable damage to economic progress and prosperity, and is disastrous to the general public or to a nation. The people must be provided with food and other necessaries. Business must be active and prosperous. Work must be furnished for carrying on the affairs of the country. If workmen are not treated as well in this

country as elsewhere, they will depart from our shores. If producers are not permitted to secure reasonable returns on their investments, their producing facilities will be abandoned and their capital invested elsewhere. We are in competition with other countries, now more than ever before, and capital here must earn a fair rate and at the same time treat labor decently and justly.

To be the "father" of one's country, compelled to consider all these intricate questions, to solve the problems confronting us, to reasonably protect all interests, and more than everything else, to satisfy the personal conscience, requires the patience, perseverance, wisdom, ability and honesty of a President like the one now administering the affairs of this country. We should strive to hold up his hands; we should pray for him and not find fault or condemn. He is doing better, much better, than any one who unjustly criticises him could do if in his place.

From what has already been said you are probably at least mentally inquiring, what is to be done? What is now proposed? How can business be done with fairness and with justice, except by the adoption and enforcement of laws which absolutely control business as to prices, rates, deliveries and all other particulars, and which secure proper treatment of every one, even though this would necessarily interfere with full, free and unlimited action on the part of all different groups in the advancement of their own interests respectively?

Every one should attempt to answer these questions for himself or herself. A proper answer would be that the natural law of supply and demand should not be interfered with by the Government or by any administrator of the laws, except in cases of turpitude, and this applies to all business transactions. There are already too many man-made laws, and perhaps too many attempts to apply them, which are calculated to interrupt and hinder progress and industrial prosperity.

The utilization of the great wealth, natural resources and productive capacity of this country should be permitted without interruption or hindrance up to the limit of propriety. But how shall this be accomplished since laws and their enforcement provide the only absolute rule for the conduct of persons? The answer is, by the enforcement of all those laws which establish order and safety of person and property as against riot, physical force and intimidation; enactments or amendments which permit immigration of foreigners on the basis of quality rather than numbers; and new laws or amendments which permit and require full publicity of economic transactions so far as they affect the public welfare.

We have not fully appraised the value of publicity. Its practical results and its necessities in all departments of economic life without discrimination or exception have not been given due consideration. The full exposure to the people of business methods and management on the part of public and private institutions and organizations will create and firmly establish a powerful, effective and satisfactory public sentiment, which, on the average and for the long run, will be more potential than penal statutes.

Investigations by legislative committees sometimes have been of great benefit in exposing to the public facts relating to misconduct or mismanagement, and have resulted in correcting existing evils; but more frequently they are harmful because unfair, politically partisan and managed without regard to rules which govern legal procedure. The committees are often made up largely of lawyers, some of whom are inclined to deal in personalities, are vindictive and arbitrary, and as the witness or other person subject to investigation is not usually permitted to have a lawyer to represent and protect him, great injustice is likely to result. All inquiries for the benefit of the public concerning private affairs, to be effective, must be made with strict honesty and impartiality. When the public is constantly given

all proper information concerning business, after ascertained honestly, impartially and intelligently by a Government Board of undoubted ability, non-partisan in character and including every branch of industry without exception, the public interest will be protected and not before.

This is not for publication, if there are any newspaper men here. We have in Washington today a commission or department that is supposed to represent the public interests. I may be misinformed, but I have been told that it is very partisan, very partial, very unreasonable, not acting really for the purpose of ascertaining facts that the public ought to know and thereby protecting the public, but for the purpose of carrying out some particular theory or motive which is not commendable and therefore carried on really in such a way as to not only do injustice to the private concerns which may be interested or involved in the inquiry, but for the purpose of promoting some particular theory that the general public is not particularly interested in. I pronounce no judgment concerning this body, but if such a tribunal as that is in existence the public ought to know it; it ought to be exposed; and it should be known in some way, as it can be, whether or not they are acting in the interests of the public or acting for private and selfish reasons.

We have been passing through an industrial conflict, involving commission of crime, heavy losses in commerce and industry, both to capital and labor, and deprivations to the general public which reached almost to the brink of extreme suffering and death, carried on by one side whose methods and amount of money expended, or the purpose of the same, were not exposed to the public view. Fortunately a wise, patient and fair-minded administration was willing and able to materially assist in bringing about a cessation of hostilities.

There is nothing to be said at this time against labor

organizations or their leaders; certainly there is or should be no personal animosity. But to permit any group, and this representing only a minority in its branch of industry, to be exempted from publicity, is an injustice and a wrong to the general public.

It goes without question that in business there are numerous matters relating to operation and management which are of interest only to the persons or concern connected, and these need not and should not be divulged to the general public, some of them particularly before consummation of pending negotiations; but as to the matters which at the time affect the public welfare there should be the right to have inspection by a competent, disinterested and non-partisan body. Let us demand in this country full, fair, impartial, competent publicity, applied without fear, favor or discrimination.

The steel industry should and would welcome such a condition. It was proved to be desirable and proper during the panic of 1907 and a short period succeeding. It is true, complaint was made by a partisan congressional committee in regard to the addresses made at the meetings, notwithstanding they were all recorded and reported to the law department and other departments in Washington; but the courts held they were proper and highly advantageous to the public, though they also held, as they ought, that what followed months later on the part of a few individuals was objectionable. There is no good reason why the public, through proper agencies, should not be present at private meetings of groups. It is, however, wrong to treat any branch of industry differently from all others. Of especial interest just now is the treatment, with like rules, privileges and penalties of both employers and employees. Unless and until that is brought about there can never be industrial peace nor can the public interest be protected. The untrammeled right to contract and the right to enforce contracts, both based on the law of supply and demand, together with opportunity on the part of the public to have the facts

exposed, are essential to the protection of the public interest. Partial, prejudiced or incompetent investigations will not suffice.

The doctrine of supply and demand, which is one of mutuality, is germane to the present public and private discussions relating to the enormous debts owing by certain foreign nations to the United States. They were voluntarily, openly and fairly contracted. They cannot properly be cancelled or disposed of on any other basis, without doing violence to well-recognized principles of justice and rules of propriety. To cancel these debts or any part of them without full payment would be forced charity, and that is never agreeable to the donor and, as a rule, equally disagreeable to a self-respecting person or nation. It is the individual citizens of the different countries who are to be consulted and whose decisions must control. Americans generally would not be contented with governmental action which relieved from debt the citizens of a foreign nation by increasing the burdens of the former. Likewise foreigners generally would oppose any such enforced act of charity. Certainly it would be abhorrent to the businessmen and women of both countries. This attitude has no bearing upon the question of furnishing charitable and Christian relief to foreigners who are in distress and need immediate aid, which cannot be provided at home. This has always been and will continue to be done by the people of every land. Each of you has done what you could, reasonably, in charitable contributions, and this will undoubtedly continue to be your habit.

The attitude and conduct of a nation should not be different from that of an individual. If your friend is in real need and is honest and trustworthy you will assist him by donation or by loan, or both, but in the latter case you do not expect him to turn the loan into a gift if and when he is in any way able to pay. If he attempts this, your respect for him vanishes. To retain your confidence he must use every effort, up to the limit of his ability and

opportunity to earn and to pay. Especially do you insist he shall work, and work hard, in any capacity offered, for this is what you would do if similarly situated. You would, of course, extend the time of payment if absolutely necessary, but you would not do so if he were keeping an automobile or eating terrapin or liberally extending his business in order to compete with you.

In the judgment of many of us the foreign nations can and are willing to pay their debts, some sooner than others, and most of them sooner than is now generally admitted. This we have publicly asserted several times. We know something of their capacity to work and earn and save and thrive; of their success in business and their mode of living. No doubt, in many instances, productive capacity has been reduced and we share in their suffering on account of deprivation. We should be cheerfully willing to extend payment at reasonably low rates of interest. We should be glad to make new loans whenever we are confident they will be paid, and thus assist in restoration and rehabilitation. We should be friendly and helpful, responsive to the chords of gratitude for friendly assistance in the past, demonstrating by word and deed that we desire a continuance of the friendship of our acquaintances abroad.

But there is no "royal road" to success. There is no way of paying debts, of receiving benefits, of acquiring property, of securing and retaining positions of employment or office, public or private, or obtaining assistants or workmen, skilled or unskilled, except on the basis of reciprocity, of returning fair equivalent to be mutually agreed upon. Every man or nation in order to measure up to obligations must work, and save; must be prudent and fair and economical.

All this applies to the payment of debts, to the re-establishment and progress of business, to the money rates of exchange, to the financial and other exchanges of commodities or activities. It is insisted rates of exchange cannot be restored or maintained except by obedience

to the simple rule of supply and demand. Foreign debtor nations need not expect a return of fair rates of exchange except by producing and selling to other countries what can be utilized by the latter. It is believed some, if not many, of the great debtor nations can produce more than they are now producing and can, without suffering, materially increase their economies. When a man or nation is in debt there should be practiced at all times rigid economy and maximum industry until after debts are paid and the equilibrium of the basis for exchanges is restored. It is needless to ignore the well-tried law of supply and demand. It cannot be done successfully.

Personalities have not been indulged in. It has been intended only to discuss and apply rules and principles of common knowledge; to call attention to the fact that artificial expedients cannot be satisfactory or successful. Every nation, every state, every people, every class, every group, every man, woman and child must always be treated fairly, reasonably, justly. Every one must act with due regard to the rights and interests of all others. This is the panacea for all human troubles.

It is to be hoped there will soon be held in Washington another peace conference for the full and frank discussion of all unsettled financial, commercial and industrial questions in which our people are interested, directly or indirectly, to be participated in by able, open-minded, well-disposed representatives from the different nations, such as those who appeared at the recent limitation of armament conference. If there shall be such a meeting, and the delegates are all of the type referred to, there will result incalculable good to all who are parties. They would not decide or discuss how to abolish or overcome the old established law of supply and demand, how to avoid or repudiate existing legal obligations, but rather how and when to fulfill them without irreparable injury to anyone or the sacrifice of principle. It would be found that the United States is always disposed to be just, reasonable, lenient, impartial and

friendly. While it is true that members of such a conference would be compelled to consider, and in a large measure be governed by, the wishes of their respective constituencies, it is believed that the large majority of the populations making up such constituencies would be sensible and honest.

The world, now more than ever before, needs peace, international and domestic, political, social and industrial. It is a time for work, economy, saving, thrift; honest, reasonable and intelligent recognition, observance and enforcement of the rules of law, propriety and common sense. Gentlemen, what we preach let us practice, conscientiously, persistently and loyally. Let us always transact our business on the basis of rendering a full equivalent for what we demand or receive. Thus we shall best succeed and prosper.

Business Conditions

There are no obstacles to continued prosperity in the iron and steel business of the United States except such as may arise from interference with the natural course of supply and demand. There is a great abundance of high quality iron ore; steam, gas and coking coal; limestone and other raw products, all within easy reach; also furnaces, mills and shops of highest grades, railroads and ships for transportation, every variety of experts of pronounced ability, organizations and systems equal to any in the world; and the demand for every kind and character of steel is far in excess of capacity to produce. Steel is needed immediately for buildings and other structures, for railroads, for farms, for pipe lines, for canning, for equipment of every kind, for guns, tools and implements of thousands of varieties, for wire, ranging from the finest watch springs and piano strings to the largest cables, for cars, automobiles, aeroplanes and other vehicles for transportation of property and persons, and many other purposes.

Order books are well filled; finished steel, aggregating many thousand tons, is stored at the producing mills, ready for shipment, and this notwithstanding the recent labor troubles at the mines and in transportation circles. Unfortunately there has been an interference with the mining and delivery of coal and with the transportation of finished iron and steel, and there is an insufficient supply of labor.

If the natural course of business had not been interrupted we would now be enjoying success and prosperity in our industry greater than ever before, so far as volume is concerned. Who is blamable? The answer is: Any one who by word or deed has interrupted or hindered the operation of the natural law of supply and demand; or has interfered with the full, free and unlimited right to work, to operate and to produce.

All that is necessary to prosperity in the United States is the legitimate utilization of our stupendous resources. We can produce here everything to supply to our inhabitants their necessities and their comforts; also luxuries and even delicacies. We can produce without limit, fuel, food, clothing and shelter; everything to make us comfortable and happy, and then have left much for other countries whenever they are in need. We would sell for cash or work or on credit; or when distress is occasioned by calamity, furnish supplies without consideration except a continuance of friendly and Christian response. We are no better than the people of other nations; and we are no worse.

The fault for lack of continual prosperity in a measure may be laid at our own doors. If so, then let us to the best of our ability overcome our faults and consistently adopt and practice reasonable and constructive policies.

Fault in many places no doubt exists. There are too many tinkers, too few experts. Many individuals, by reason of political position or other limited success, assume to know a good deal about matters, particularly economic, concerning which they have little information,

derived either from study or experience, and these generally talk the loudest and longest on these subjects. Others from a desire to control or create antagonisms or to derive personal profit, attempt to interfere with the natural and reasonable course of business, sometimes resorting to force and brutality. We must keep our own houses clean, search our own hearts, remain true and loyal and above reproach, and then openly proclaim the truth at proper times and places.

Just at this time it is generally recognized there is a shortage of labor, although now and generally there are considerable numbers of idle men who do not ask for or desire steady work. For various reasons many workmen have returned to their homes in foreign countries. Business here was dull, and besides, these men on account of very large wage rates had accumulated money and believed themselves to be independent. The shortage in labor, however, has come principally as the result of the percentage immigration laws which have limited the number of workmen who would now come to this country if not prevented by the laws referred to. After some experience these laws are now believed by large numbers to be unreasonable. Ostensibly, at least, they were aimed at the sudden and large increases in the foreigners who were locating here, many of them entertaining views hostile to the ideas of our Government. These laws ought to be promptly changed. The restrictions upon immigration should be directed to the question of quality rather than numbers of foreigners coming to this country. Measures for limiting the number of immigrants to those who are clearly shown to be healthy, morally, politically and physically, ought to be clear, strict and enforceable; but the number allowed to come here should be equal to the necessities of our industries. The administration of the law could be under the control of a competent and impartial governmental commission or department, to be managed for the benefit of the general public and not for the protection of any special class or the

exploitation of any impractical or injurious theory. This is one of the most important questions now being debated throughout the United States.

In spite of the difficulties which have confronted industry and appreciably frightened investors, the manufacturers of steel are now producing, on the average, about seventy-five per cent of their estimated capacity. This is more than double the total capacity twenty years ago. We are making a better quality of steel, are increasing diversification of shapes for additional uses; and in many ways we are extending capacity and effecting economies, although selling prices have not kept pace with larger costs. We shall soon get back to a basis of business that will yield fair profits, if permitted to proceed without unreasonable interference.

As to general business conditions, in addition to what has already been said, great significance should be given to the publications concerning the enormous savings bank balances. These show conclusively a disposition to economize, whatever may be the reasons. Economy and saving are fundamental to thrift and prosperity.

In this greatest, richest, most admirable country there should be the continuance of prosperity without prolonged depressions. The iron and steel industry can be a decided influence toward progress and stabilization.

Judge Gary: Mr. Cook suggests, and I agree with his suggestion, that those who desire to present remarks, criticisms, or whatever they may be termed, concerning what is said today by the speakers, should do that in writing, and their criticisms will be printed. We have not time to give for much discussion, although if anyone desires now to criticise what I have said he certainly should have that opportunity. While I am presiding I should not cut anyone off from that.

Our first paper is on Modern Methods of Mining Coal, by H. Foster Bain, Director, Bureau of Mines, Washington, D. C.

MR. H. FOSTER BAIN: The paper which I have to present to you today is the result of a series of conferences of the engineers of the Bureau of Mines and friends outside of that organization. I am merely the mouthpiece in presenting the paper, so that you should think of it as coming from them rather than from me.

MODERN METHODS OF MINING COAL

H. Foster Bain

Director, Bureau of Mines, Washington, D. C.

The events of the past year have emphasized, as perhaps never before, the fact that the welfare and prosperity of our people and the strength and permanency of our government are largely dependent upon the steady operation of our coal mines. In order to bring about such operation in any satisfactory degree, three distinct conditions must be satisfied:

1. The men employed in the industry must be given opportunity to enjoy the profit of their labor under such environment as conduces to good citizenship.
2. The owner must be given assurance of opportunity to derive a profit from his investment.
3. The government must be assured that there will be no serious interruption in the normal flow of coal to the people and the industries.

Planning a Mine

The problem of organizing or reorganizing the coal industry, so as to permit it to meet these conditions, is now engaging the serious thought of the nation. It is not my purpose here to attempt any such ambitious program, but rather to point out some of the technical and nearly related matters which enter into any solution of the main problem and to indicate a few of the lines of progress in technical work which have bearing. What I have to say is based upon the observations made in the past decade by the engineers of the Bureau of Mines, and in assembling them I am principally indebted to Mr. J. W. Paul, Chief Coal Mining Engineer of the Bureau. Since the problem of coal storage is to be

separately discussed at this meeting, it will be passed over here, though storage is one of the means that can be best used in bringing about such measure of stabilization of the industry as conditions permit.

Coal mining, as is true of nearly every other branch of mining, must always be organized and conducted with an eye to the fact that enterprise is founded on a wasting asset. In the development of any coal property first consideration should be given to the probable life of the mine in determining the type of plant, its layout on the surface and underground, and the housing of employees. In the development of a mine and its operation, there is no sentiment; but in the making of homes for a new generation, there is much sentiment—at least this should be cultivated for the benefit to be derived in good citizenship and the reflex on operating conditions. It is not always easy to harmonize the two conditions that are here opposed to each other. To build a new community of people with modern facilities, conveniences, and surroundings, a long life is desirable; whereas a modern mine should be operated at its maximum capacity and be worked out in the shortest possible time. In practice these do not stand as much in conflict as their mere statement suggests. Modern mines are so large and are built to operate on so grand a scale that the life of the investment, of the mine, and of a single generation of workers do not fall far apart. Intensive work and quick return bring, as always, the larger return, but the continuing market permits economic adjustment of mine life to meet social conditions. One might make more money by mining the coal in ten rather than twenty or thirty years, unless this involved building a new town and bringing together a new community every ten years. This is expensive.

Taking account of the social and economic results of opening a mine, no new properties should be opened save (1) when there is prospect of a shortage of coal for future needs, beyond the capacity of the existing

mines; (2) when, by the adoption of modern methods, coal can be produced cheaper and sold cheaper than from going mines using antiquated or out-of-date methods; and (3) when it becomes necessary in order to conserve coal resources and get the greatest possible recovery from a given area.

The greatest economy and conservation, and the cheapest coal, will result when all mining is done along modern lines—that is, when the mines run full time and the capacity of the mines is not greatly larger than the consumption. This condition, however, is more ideal than practical in a country where mines are widely scattered, consumption is seasonable and the whole matter of development is left to individual initiative and control with combination forbidden by law.

Despite all discouraging factors, capital has continued to flow into coal mining and more, larger and better mines are being continually opened. The predominating incentive in the adoption of modern methods of mining is economy, and effort is directed toward decreasing the cost of the finished product of the mine. Because of their final relation to cost, any system of mining must give consideration to the capital invested, the character of the safety precautions, and the efficiency of the workmen and machinery employed. The state is most directly concerned in the safety and health conditions, and in modern mine development these are, by common consent, put first. One method of meeting these conditions is the concentration of labor and machinery in the smallest practicable area in each mine at any one time. This permits close personal supervision and insures the conduct of the work in accordance with detailed, carefully thought out plans. It also minimizes accidents and gives greater efficiency as to both labor and machinery, and a greater recovery of the coal. Accordingly there is a gratifying increase in the tendency toward intensified production. In order to realize fully the benefits of

such a system of work, it is necessary to lay out the mine itself with that end in view.

In the selection of the method best suitable for the development of any particular coal bed, certain natural and geological conditions must be given careful consideration. These are, the nature and thickness of the coal; its inclination from the horizontal; the direction of any cleavage planes present in the coal or overlying strata; the character of the immediate roof and overlying strata; the character and nature of the floor, and the depth of cover over the coal bed.

In most of the important coal fields there has been by now sufficient development to bring out many of the engineering problems that must be solved in planning a new operation in that field. Nevertheless the method most suitable for the mining of any coal bed can only be determined by experiment extending over a period of several years, sufficient at least to work out several sections or panels of the mine.

Future generations should be considered, so far as is economically feasible, in adopting plans for development of any national resource and especially of coal. In much of the early mining little regard was paid to the systematic extraction of the maximum percentage of the coal, although in many instances this was entirely practicable and failure to take this into account was due merely to the absence of a better plan. Today there have been developed such a variety of methods of mining, which have proved economically successful under so many different local conditions, that no real excuse exists for the adoption of wasteful and uneconomic methods.

The centralization of control and management of large tracts of coal and of many coal mines has brought in better engineering and better management and has spread the benefits of the development of better methods of mining with a resulting notable increase in the percentage of recovery. This has been accomplished by

scientific management and the employment of engineers of wider outlook, an example that has been followed to great advantage by the smaller operator.

Machinery vs. Men in Mining

In the early days of mining there were three essentials that had to be provided by the operator before men could work in a coal mine—namely, mine cars, a track and ventilating currents. Now these have been augmented to the point where a modern mine requires as well, electric haulage motors, mining machines, loading machines, and in some instances a mechanical conveyor system which dispenses with part or all of the underground system of tracks and mine cars. Our mines are gradually being converted into vast machine shops, which require the employment of specialists in various mechanical lines to keep the machinery in efficient working order. This is in line with the modern tendency to take the load off of the men and to put it on some machine, making the men supervisors of machines rather than substitutes for machines. It requires more capital and less men, though the latter must be better men, better trained.

About the year 1889 there were introduced in the coal mines electric coal cutting machines, and from the date of their introduction they have been a success, although the earlier types have undergone changes in mechanical design and their capacity for coal cutting has increased. In 1891 the average coal production per machine used was 11,398 tons, and this had increased in 1918 to 17,545 tons.

According to the report of the Bureau of Census, in the year 1919, out of a total of 8,282 coal mines in the United States there were 3,870 mines using mining machinery producing 367,565,092 tons of coal, as against 4,412 mines without mining machines producing 92,860,744 tons. These figures may be a little misleading, since

in many mines in which mining machines are used there is a large tonnage produced without the aid of the machine. The latest published report by the United States Geological Survey, giving data on coal production, gives the machine-mined coal for 1918 as 55.9 per cent of the total bituminous production.

The various social aspects of coal mining have come to occupy a position which must be taken into full account even in the initial stages of planning development. The change in the character of the labor available makes necessary special thought in planning the mine and the mine town. In recent years there has been an increase in the number of employees who come from Southern Europe. These people have customs that differ from ours, and their ideas of government are not in harmony with our Anglo-Saxon way of doing things. If we are to live and work together, they must be taught our own ideals; consequently one of the purposes of the welfare department, which is now a part of any large mining organization, is to foster and teach Americanization. This is a problem that is squarely up to not only the mining interests, but to the American people, and in passing it is pertinent to call attention to the fact that the mining interests are alive to its importance. Welfare work is one of the items of expense which must be included in the production cost of a ton of coal.

Choice of Mining Method

The seasonal character of coal mining has already been mentioned. It has been so much discussed in recent years that mere mention is sufficient to call to mind how deeply it cuts into the economies of mining. What is perhaps less generally recognized is that it similarly influences technical conditions. In order to do clean mining it is of first importance to have a good line of break across the workings. This should be as long as the size of output demands and should be kept moving across

the property at the steadiest rate possible. Any interruption is apt to result in loss of coal and increase of cost. It is possible to use, in steadily operating mines, systems that fail in those subject to irregular and long stoppages. The problem that the engineer faces is that of modifying ideal systems to meet actual conditions, and in coal mining one phase of this is the division of the field of mining so as to control the break according to the probable market. It is one of the hard conditions faced by the industry and, while some amelioration may be anticipated, bituminous coal mining in the United States seems likely for a long time to come to be influenced greatly by seasonal demands.

Any discussion, therefore, of mining methods must have in mind not only the ideal possible where steady operations can be predicted, but the modifications necessary to adapt each system to temporary stoppages. With this in view I shall review some of the modern plans of operating coal mines and the conditions that affect safety, economy and efficiency. The accompanying maps and diagrams, reproduced from actual working maps generously placed at the service of the Bureau by the various companies, will serve to illustrate what is being accomplished.

Double-Entry, Room-and-Pillar

Figure 1 is a reproduction of a plan of a mine developed on a common double-entry, room-and-pillar method. The ventilation of such a mine is accomplished by a continuous current of air, and any gas evolved on the intake is conducted to men in other parts of the mine. This may be of an explosive nature, and since the air is directed by the use of doors, it will be apparent that leaving open a door may result in an explosion and loss of life. The contaminated air is unpleasant to breathe; some men will suffer from illness brought on by lack of good air; and there will be a general decrease in efficiency.

In many mines operated on this plan, active operations are widely scattered and at most times parts of the mine are not being worked. The foreman has time to visit the active working places only once in two days perhaps. The mule-drivers have long distances to haul the coal to places of assembly. The maintenance of the track and the cleaning up of falls become items of much expense.

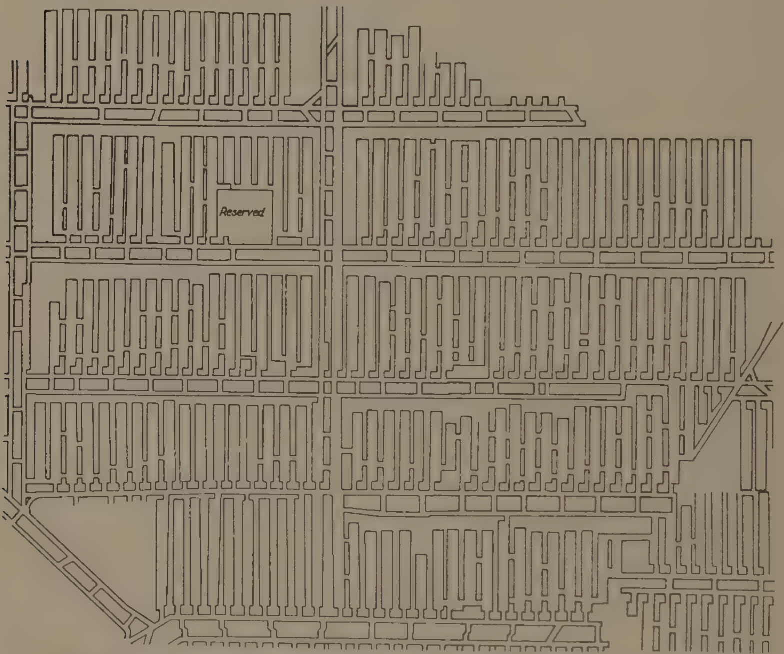


Fig. 1—Double-entry, room-and-pillar method. Pillars not recovered.

The rooms are driven on the advance, and the pillars are thin and are left standing after the completion of the rooms. When an effort is made later to draw them, it is usually found that many roof falls must be removed, new ties and rails laid, and after a few pillars are partly drawn, the weight of the overlying strata crushes the remainder and that section of the mine must be abandoned. This crushing often extends over the haulage entries. The total recovery of coal may be only 50 or 60 per cent,

and as a result of the squeeze the capacity of the mine may be reduced 50 per cent. In this example, with a recovery of only 50 per cent of the coal, it requires the mining of two acres to secure the quantity of coal in one acre.

It does not require an expert accountant to determine that coal produced from this mine will be at the maximum expense; that compensation on accident insurance will be at the highest rating; and that there will be large waste of coal which can never be recovered. This method of mining is still in vogue in various parts of our country.

The Panel Method

A more advanced plan of operation is known as the panel, room-and-pillar method. This system admits of large tonnage capacity, but it may be abused, and one of its chief purposes may be overlooked or sadly neglected—that is, the recovery of the greatest percentage of the coal.

In the thick beds of Franklin and adjacent counties of Illinois, there are some mines of very large capacity operating under a surface which is not especially valuable for agricultural purposes, and has little value compared with the value of the underlying coal. The assumed value of the land, however, still influences the method of mining and despite the fact that in practice the workings do cave through to the surface, coal is sacrificed underground in the form of pillars originally designed to hold up the roof. As an illustration of the improper application of the panel system for the recovery of the coal, there is shown in Figure 2 a plan of a part of a mine from which not over 50 to 60 per cent of the coal is recovered, the remainder being lost for all time. The panels embrace 16 rooms driven on the advance. No systematic attempt is made to remove the pillars. The depth of cover is 500 to 600 feet, and the coal ranges from 7 to 9 and 10 feet thick. The pillars between the rooms

are not of sufficient thickness to hold the overlying burden until all the rooms are driven their full distance. As evidence of this, the map shows a number of irregular blocks of coal between the panels, which are lost to future

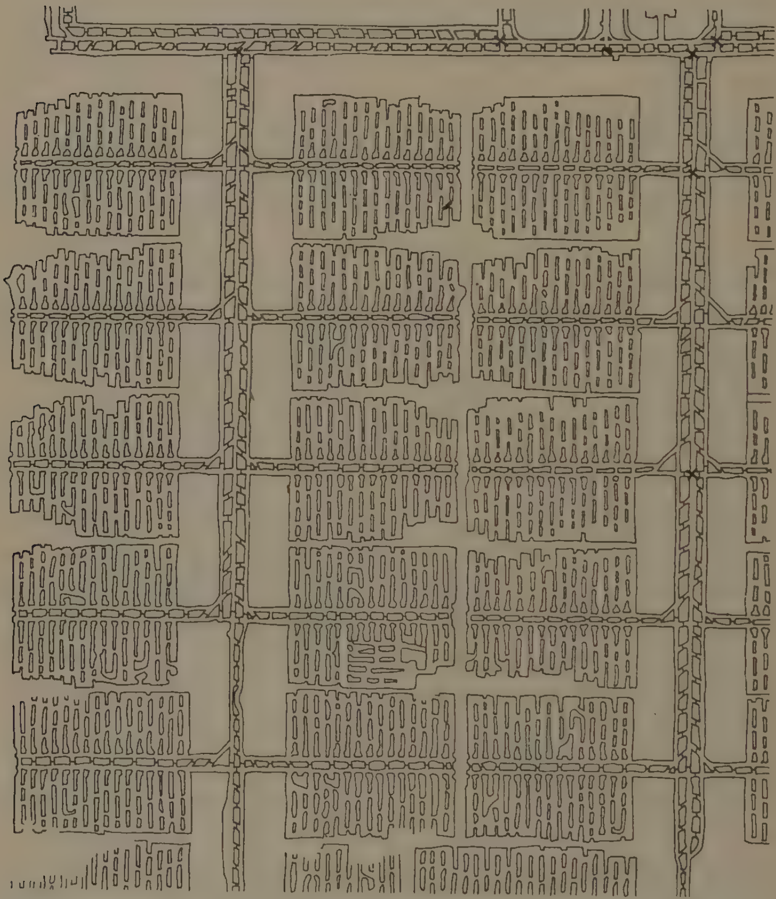


Fig. 2—Section of map of an Illinois Mine, showing panel, room ' and-pillar method.

recovery. The pillars crush to the extent that subsidence of the surface is a common result.

In the Pittsburgh coal bed in Western Pennsylvania a number of different mining methods are in vogue.

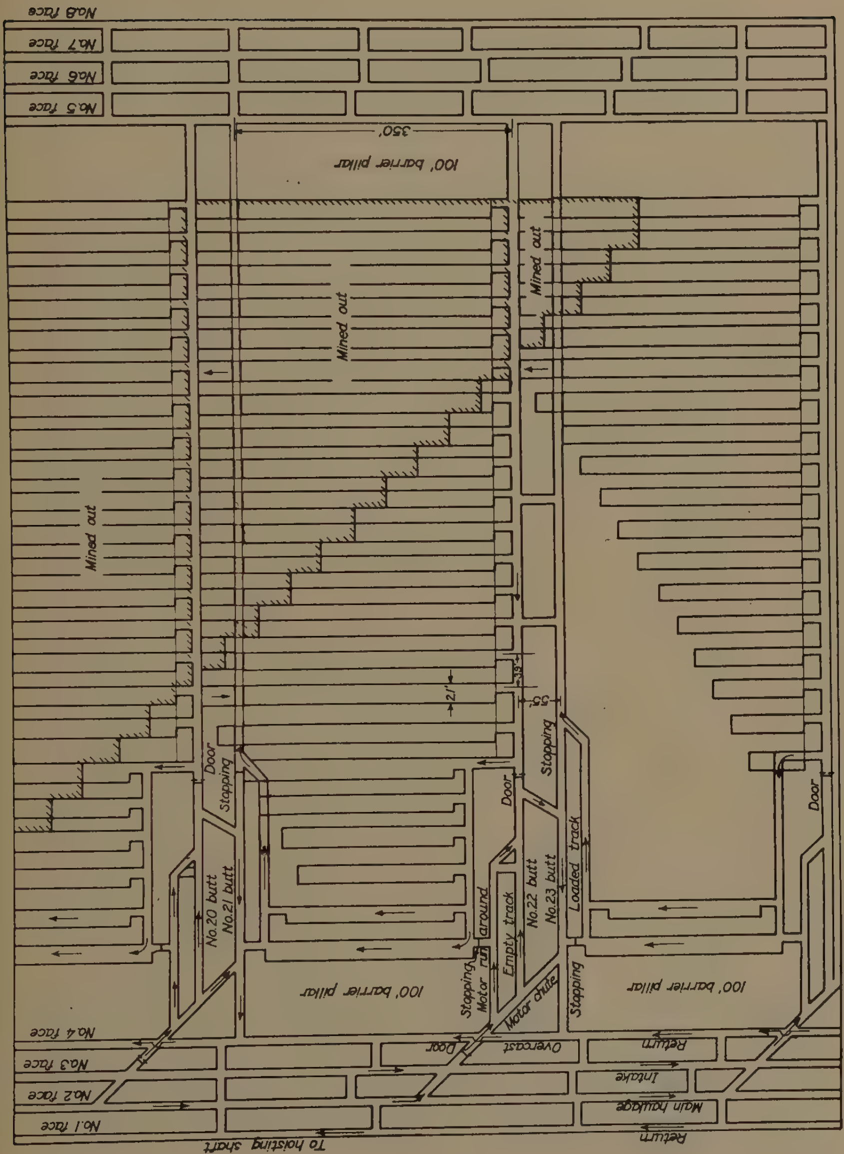


Fig. 3—Retreat method of mining, Pittsburgh Coal Bed, Western Pennsylvania.

Figure 3 is a plan of two panels, rooms and pillars which has been adopted by one of the large coal companies. This plan contemplates the panel retreating system, with a maximum recovery of about 87 to 90 per cent of the coal. A study of the map will show that the butt entries are 1,200 feet long, and rooms are 21 feet wide, 300 feet long, and have 18-foot pillars between. The innermost rooms are the first to be driven, and all pillars are withdrawn on the retreat. It may be observed that the line of break is maintained in a practically straight line over parts of these panels. As in other similar methods where large recovery is secured, the break-line must be kept practically straight to ensure proper breakage of the roof, and prevent crushing of the coal on the ends of the pillars.

In some coal mines the nature of the roof and floor is such that it is of great advantage to work out a panel in the shortest possible time, and this quick extraction, particularly of the pillars, permits of getting a higher percentage of the coal; also coal of a better grade, with respect to lumps.

The details of the plan of development of a panel, room-and-pillar method, as conducted in the Pittsburgh coal bed in Western Pennsylvania, are shown in Figures 4, 5 and 6, each showing the same panel in progressive stages of development. This method is best adapted to mines which do not have an extra heavy cover or a roof that is difficult to break. In gaseous mines, the practice in Pennsylvania is *not* to conduct to the live workings air that has passed over or through the goaf.

Figure 7 shows a modification of the method, adapted to long entries of a panel. The rooms are first driven near the center of the panel, and the retreat is toward the face or haulage entries. This saves in the length of haul from the rooms to the parting on the haulage entries, but it does restrict the length of the break-line. With this method, a large percentage of the coal is obtainable, probably 85 to 90 per cent.

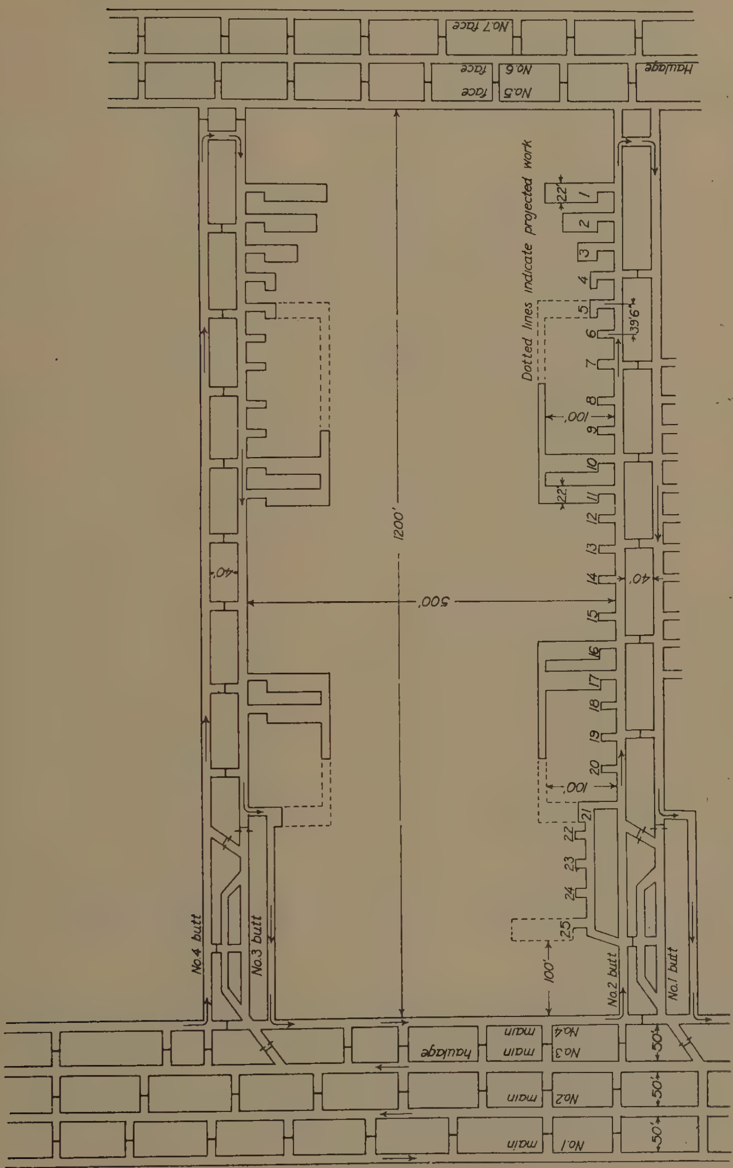


Fig. 4—Sketch showing first step in method of drawing pillars, Pittsburgh Coal Bed, Western Pennsylvania.

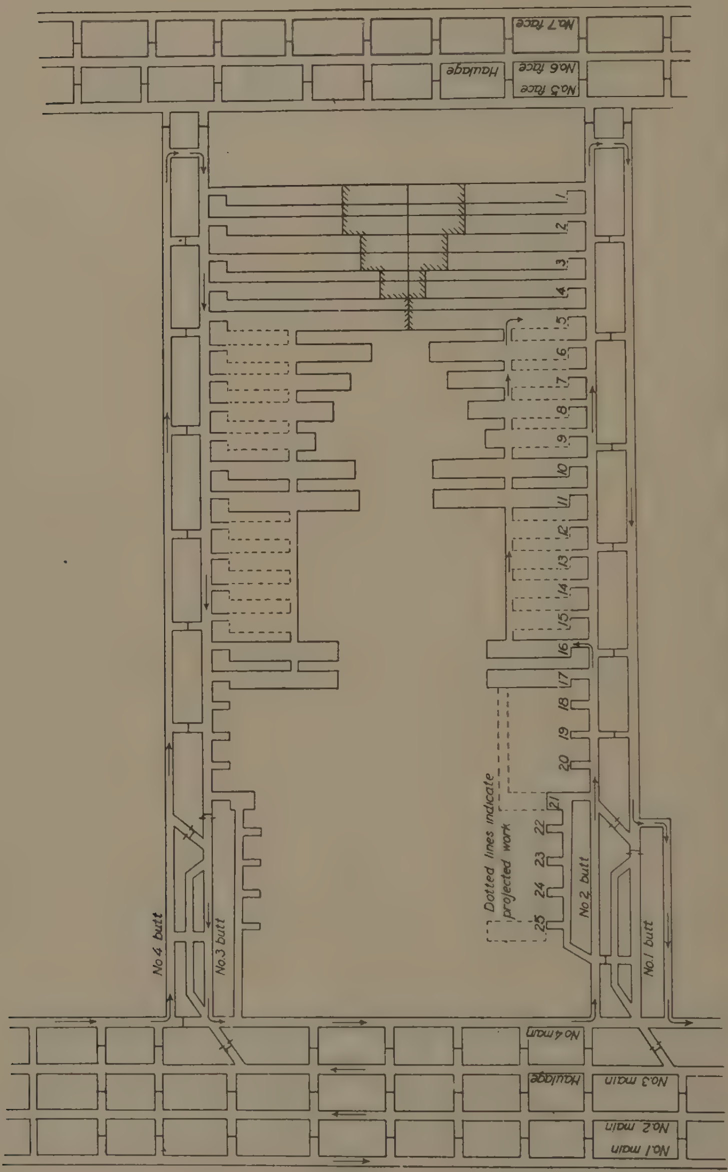


Fig. 5—Sketch showing second step in method of drawing pillars, Pittsburgh Coal Bed, Western Pennsylvania.

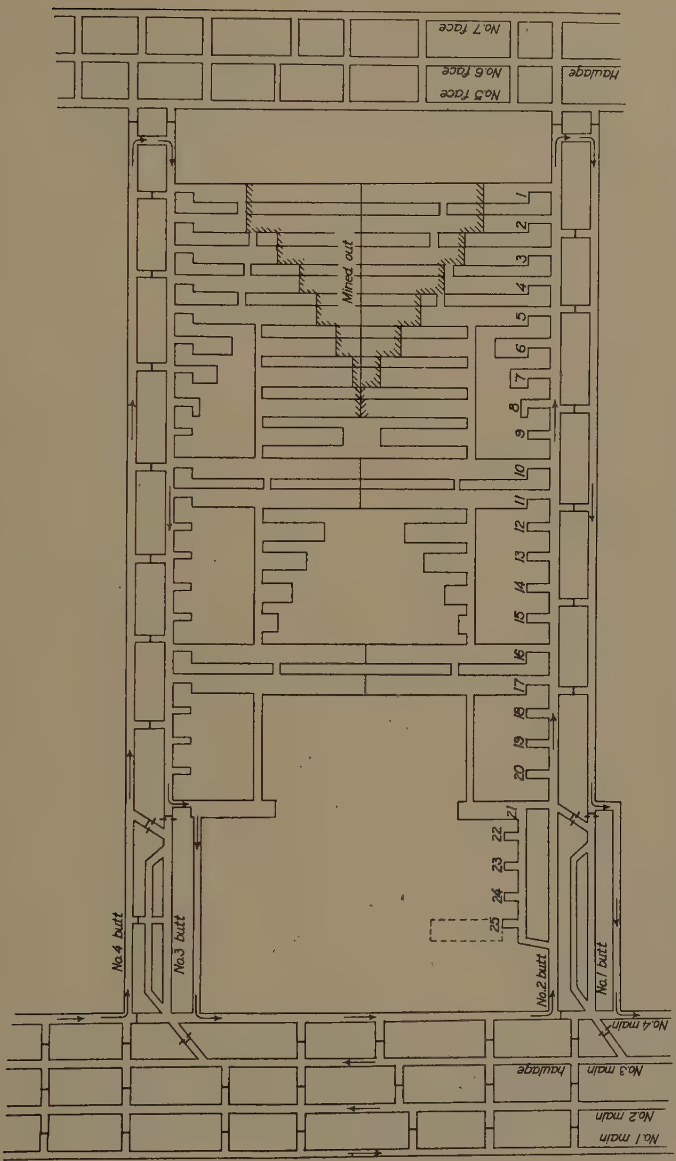


Fig. 6—Sketch showing third step in method of drawing pillars, Pittsburgh Coal Bed, Western Pennsylvania

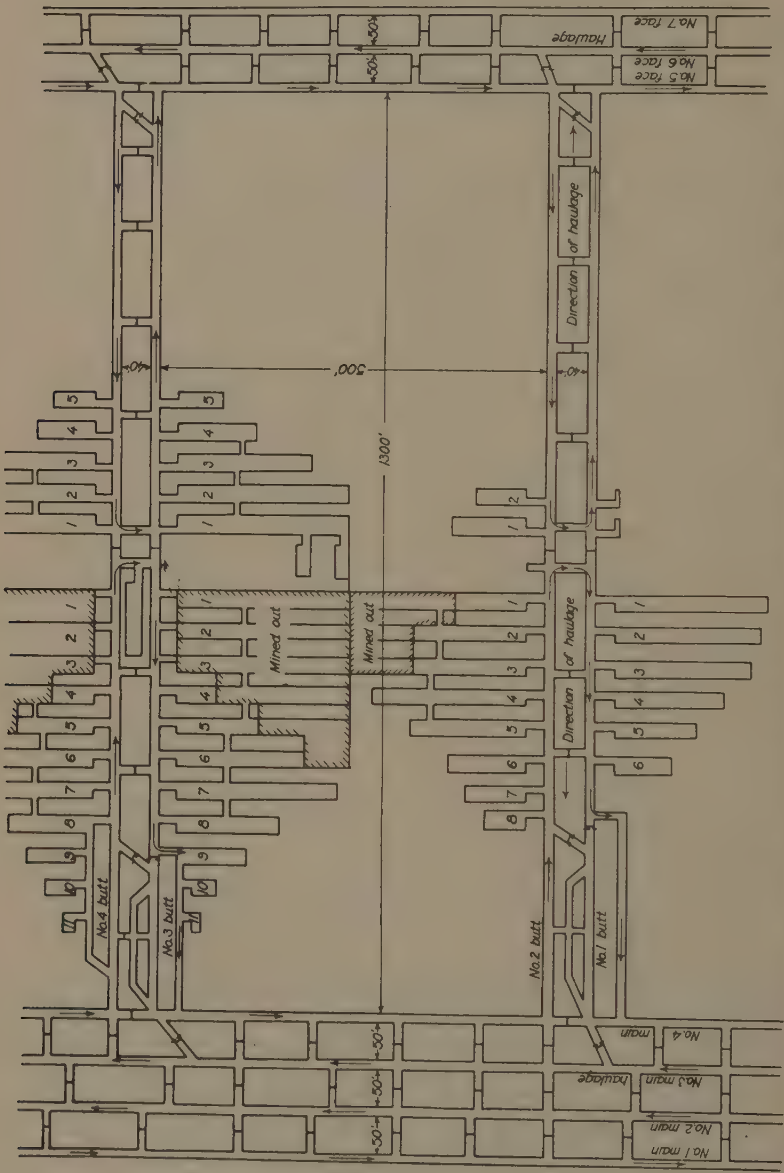


Fig. 7—Sketch showing system of drawing ribs on long butt entries, Pittsburgh Coal Bed, Western Pennsylvania.

Pocahontas Field Methods

The methods of mining in southern West Virginia in the celebrated Pocahontas coal need little additional publicity other than words of commendation for the efficiency of the system which gives such high percentages of recovery. The system in general use in this field has been fully described in the proceedings of several of our technical institutes* and in the technical press†, and special reports.‡

It will be sufficient for the purpose of this paper to reproduce the general outline of the plan of development. Figure 8 shows such a plan, developed on the panel, room-and-pillar method, which admits of both the advance and retreating method of development of rooms and the drawing of the pillars. Figures 9 and 10 show the details of the process of removal of the pillars. From actual records of surveys of mines and railroad weights of coal shipped and of coal used at the mining plant, the recovery has been exceptionally good, having increased from 72 per cent between the period 1883 to 1890 to 87 per cent for the period 1911 to 1920; while some individual mines had recoveries of 91 and 97 per cent.

Connellsville Methods

The shortwall, Connellsville method§, shown in general plan, Figure 11, has been widely used in the Connellsville field of Western Pennsylvania, particularly in mines of the H. C. Frick Coke Company. This method is especially applicable to the development of a coal bed that has a weak or friable roof, necessitating the driving

*W. H. Grady: Some Details of Mining Methods with Special Reference to Maximum Recovery, W. Va. Coal Min. Inst., Dec., 1913, Coal Age (1913) 5, 156. W. H. Grady: Cost Factors in Coal Production, Trans. A. I. M. E. (1915) 51, 138. Thomas G. Clagett: Systems of Mining in Pocahontas Coal Field and Recoveries Obtained, Trans. A. I. M. E. (1922) 1156M. H. H. Stoek: Some Considerations Affecting Percentage of Extraction in Bituminous Coal Mines in America, Trans. A. I. M. E. (1922) 1143C.

†H. H. Stoek: Pocahontas Region Mining Methods, Mines and Minerals (1909) 29, 395. Audley H. Stow: Mining in the Pocahontas Field, Coal Age (1913) 3, 594. H. V. Hesse: Maximum Recovery of Coal, Proc. W. Va. Coal Min. Inst. (1908) 75; and Mines and Minerals (1908) 29, 373.

‡C. M. Young: Percentage of Extraction of Bituminous Coal with Special Reference to Illinois Conditions. Univ. of Ill. Bull. 42 (1917).

§Patrick Mullen: New Methods for Mining Bituminous Coal by the H. C. Frick Coke Co., Proc. Eng. Soc. of Western Penna. (1916) 33, 714.

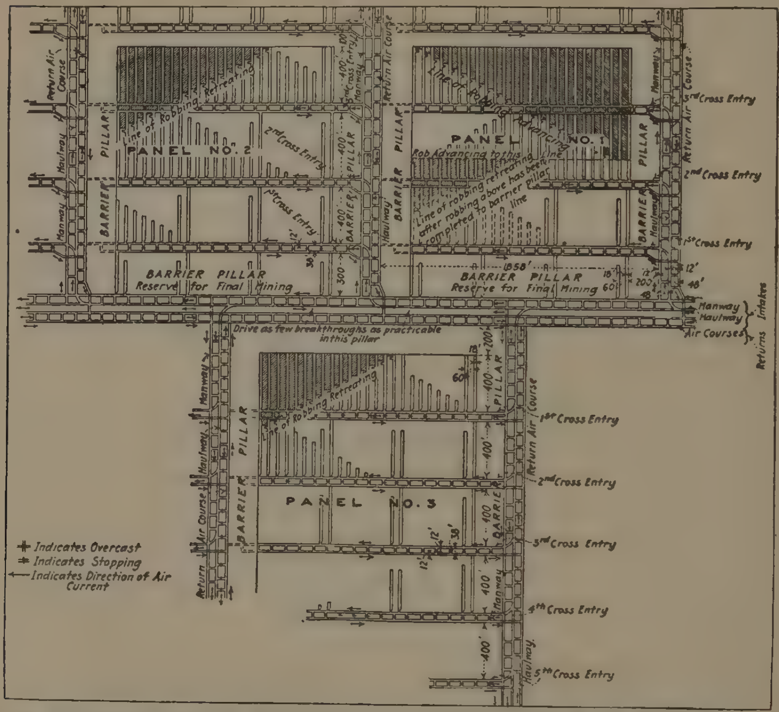


Fig. 8—General plan of mine development, Pocahontas Field, West Virginia

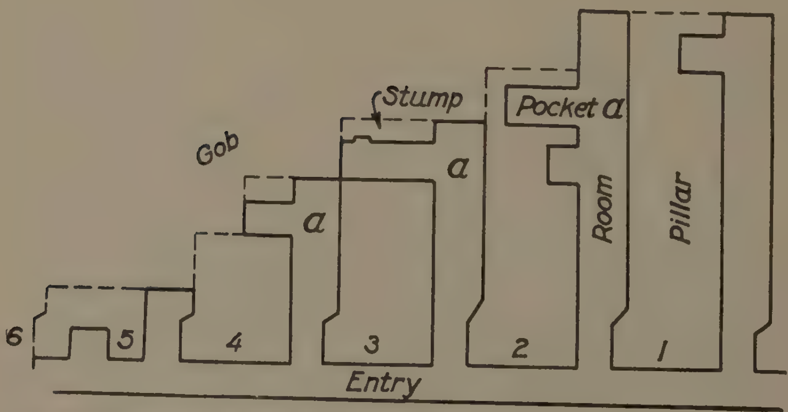


Fig. 9—Pillars are cut through as at A and the stumps removed on the retreat.

of narrow rooms, entries, and cut-throughs. The entries and rooms and other excavations do not exceed 12 feet in width. The system admits of establishing a long break-line, which, with clean robbing, gives a uniform subsidence of the overlying strata and a minimum of damage on the surface. As shown in Figure 12, the work may be so directed along the entire line of pillars as to control the daily output of the panel being worked.

This control of production is arranged in a schedule of 2, 4, 6, or 8-day intervals. As an illustration of the 2-day interval, each working face and each pillar is only 2 days in advance of the next adjacent working place,

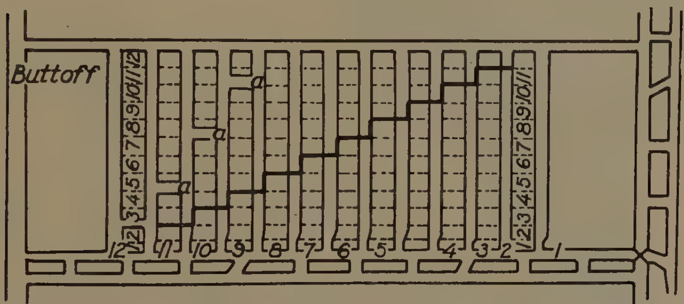


Fig. 10—Cross cuts between rooms are so located as to fit in with the cuts required in removal of pillars.

and under this schedule a new working place must be started every second day. Under this 2-day schedule, the maximum daily output is obtained, and along the working faces and pillars shown in the general plan (Figure 11), the production may be 2,000 tons. The schedule for 8-day intervals calls for the turning of a new working place off each room every 8 days. This plan of operation requires concentration of the workmen, and admits of close supervision, which ensures good extraction of the coal and safer conditions for the miners. The recovery of coal by this system is about 90 to 92 per cent. The panel or block of coal developed by this system requires the driving of entries to the boundary of the panel,

and the subdividing of the coal into practically square blocks of 100 to 112 feet on each side, and is especially adaptable for mining large areas.

The "herringbone" system, as developed in the Con-

Fig. 11—General plan of shortwall, Connellsville method.

nellsville field, is shown in Figure 13. It has been employed in a number of the mines of the H. C. Frick Coke Co. with success, giving a recovery of 90 to 92 per cent of the coal. This system is also adaptable to coal that has a weak or friable roof, requiring narrow work in

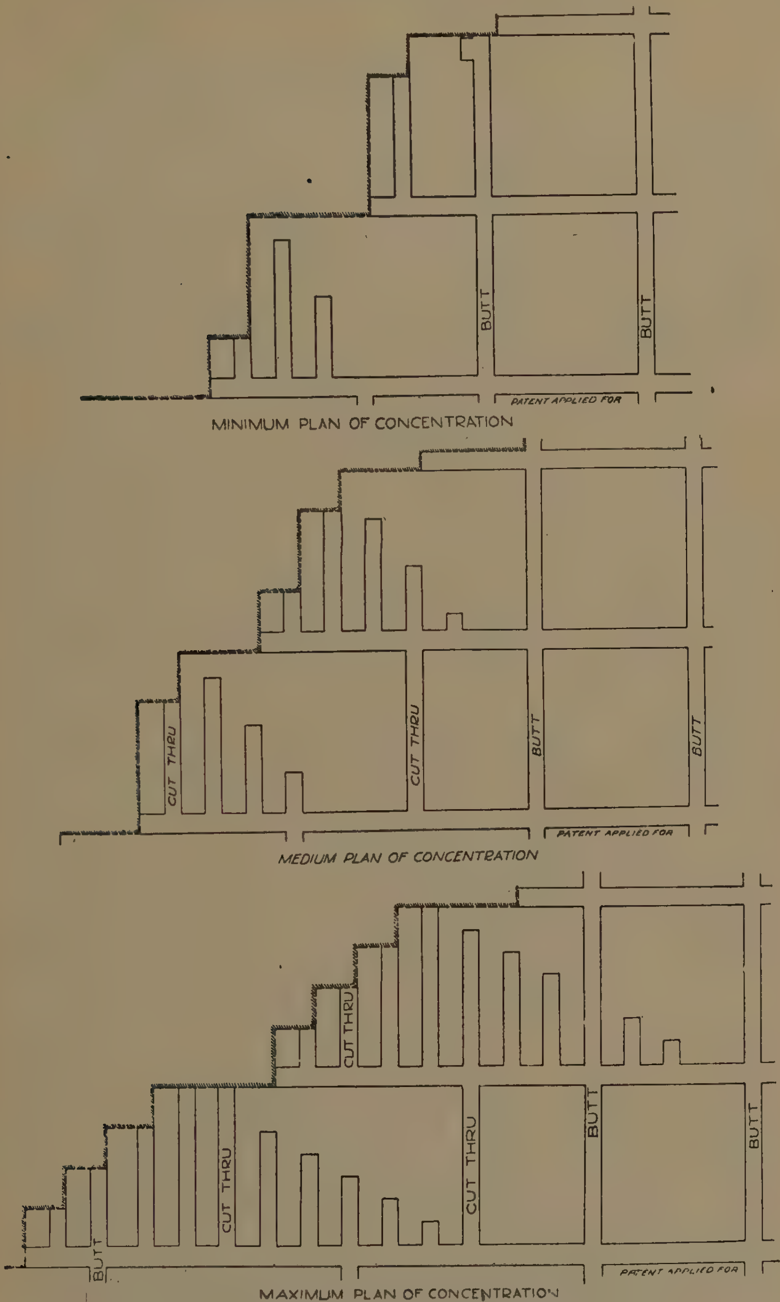


Fig. 12—Minimum, medium and maximum recovery details.

driving rooms. The rooms being turned at 45 degrees facilitates the movement of mining machines, and the ribs of the rooms aid in establishing the break-line of the roof. This herringbone system is well adapted for the quick extraction of small areas.

It is not possible in a paper of limited extent, as this must be, to present all the plans of the most advanced methods in use in the several principal mining fields of the United States; otherwise advanced methods of other coal fields could be added to illustrate economic and safety practices and high recovery of coal.

Ventilation

In the matter of ventilation, the panel method of mining is especially suitable for the control of the air currents, and in gaseous mines the splitting of the air is a requirement of a number of State laws. It admits of separate ventilation of each panel with fresh air and this adds to the general safety of the mine as it relates to gas explosions.

The panel method is also admirably adapted for the installation of methods of control of coal dust explosions, since by the installation of rock dust barriers at and near the entrance to the panel the effects of a dust explosion may be confined within the panel. This method of prevention has been installed in a number of large mines in Illinois, and has given most gratifying results—two and possibly three explosions having been localized through the action of the rock dust.

Explosives

Another element of modernization has been the rapid adoption of permissible explosives for blasting purposes in bituminous coal mines. Probably no other factor in the process of mining has contributed more toward the safety of mines against explosions and fires than permissible explosives. As an indication of the increasing use of permissibles for coal mining, and the correspond-

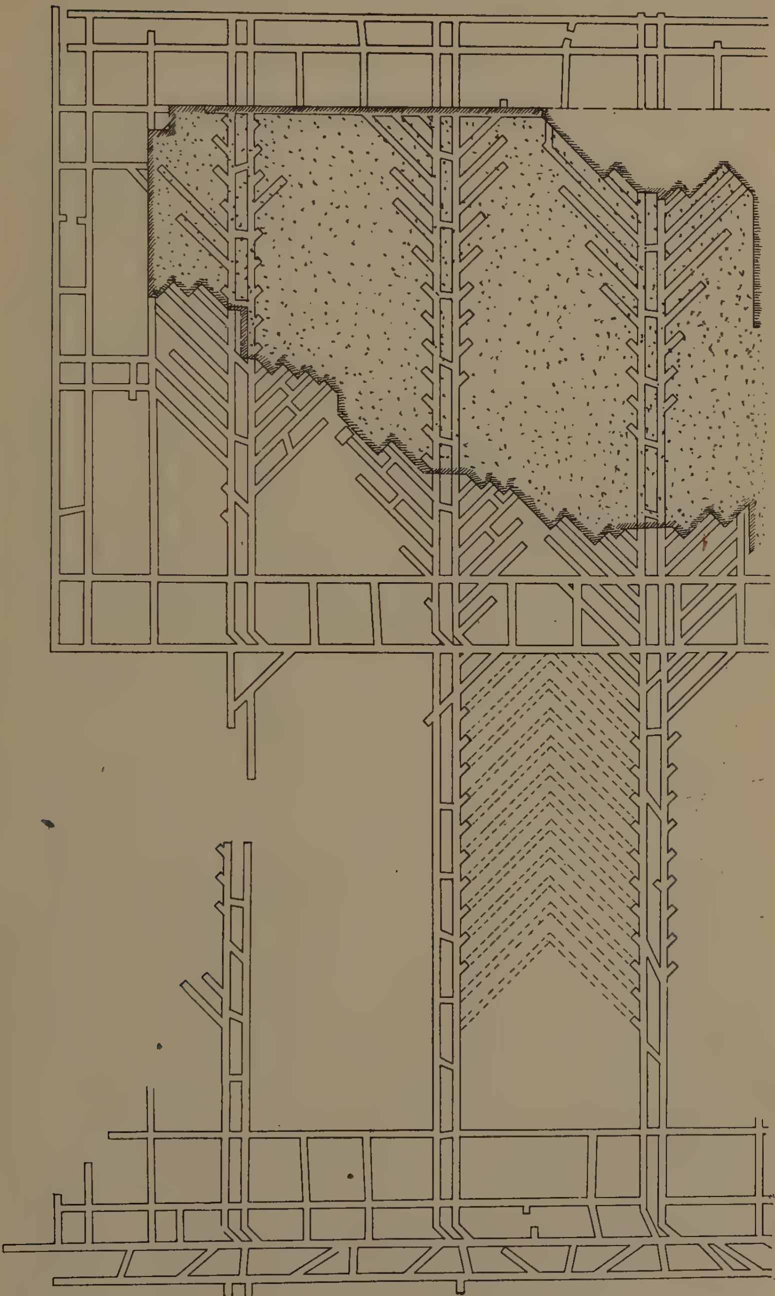


Fig. 13—Herringbone system, Connellsville Field.

ing decrease in fatalities and injuries due to explosives, the following tabulation is self-explanatory:

Year	Yearly Sales of Permissible Explosives	Percentage of Fatalities due to Explosives, to Total Fatalities
1901	None recorded	No figures
1902	11,300 lbs.	No figures*
1905	1,031,300 lbs.	7.49
1910	1,820,836 lbs.	5.09
1915	21,841,659 lbs.	4.52
1920	45,222,130 lbs.	4.44

*1903—9.80.

This record is one in which the Bureau of Mines especially takes pride, since it was the fortunate agency around which came together the miners, operators, explosives makers and State officials, who collectively are responsible for the introduction and wide use of permissibles. Having no police authority in the matter, the Bureau was nevertheless able, as the friend and technical adviser of all concerned, to bring about the introduction of this great life-saving agency in American mines.

Safety Under the More Modern Methods

Most of the arguments heretofore advanced in favor of the modern methods have been from the standpoint of greater recovery of coal and of economy in operation, but it should also be remembered that safety conditions are improved as well by the adoption of these modern methods and conduct of the work in accordance with a detailed schedule of operations. In those mines where the work is segregated, as in the concentrated method, the coal pillars are removed systematically and quickly. The pillars and stumps of coal are mined before the roof movement begins to throw excessive weight on them, and in this manner falls of roof and caving are delayed. This makes the working place safer for the miner and admits of the recovery of part of the timber that would otherwise be lost. The more modern methods seem to have

everything in their favor in safety, efficiency and economy.

Loading Machines

Machines for loading coal into cars in mines have made their appearance, and have been given trials in a number of mines in different parts of the mining fields of the United States. The general design of these machines is largely patterned after the steam-shovel, in that the machine lifts the coal from the floor of the mine and discharges into a mine car. Many ingenious mechanical devices have been used to dispense with the crane and boom of the steam-shovel design. These machines have a large loading capacity, varying up to 100 tons per hour; but none of the present mining methods will admit of the placing and removal of the mine cars to handle this capacity. The majority of the machines are not adaptable to current mining methods. It is probably true that the machines have been made for too much capacity, and machines of less capacity, lighter, smaller, and more easily portable, may be found more suitable. The machines which have been used are provided with motive power that enables them to be moved from place to place, some on the mine track and others on self-laying track such as the caterpillar. In most mines the necessity of placing timber and props for roof support has restricted the use of some types of machines; the working place affords a limited quantity of coal during any shift and frequent moving of the machine is necessary; the loaded mine cars cannot be taken away and empties furnished to meet the capacity of the machine.

Introduction of additional machinery is doubtless in the line of progress, but it will be necessary coincidently to adapt the method of mining to the machine as well as the machine to the mine. The efforts to use loading machines have thus far been confined to mines where little if any change has been made in the mining method,

other than placing additional trackage and motors to handle the coal loaded by the machine. Modification in the transportation system and in other phases of mining may be necessary to the economic use of loading machines, and may bring about their general adoption in mines where roof conditions are favorable.

As to the performance of the different types of loading machines, the engineers of the United States Bureau of Mines have been engaged in an effort to collect data on the operation of the machines. One report has been published on this subject, namely, "Underground Loading Devices in Metal Mines."*

Data regarding coal mines have not yet been systematically compiled. No uniformity exists in keeping a daily record of performance which would show the man-hours of labor, the loss of time due to shifting the machine and mine cars and to breakage of any parts, and the renewal of parts, all of which enter into the cost of operation and maintenance, and are reflected in the cost sheet, which latter is the appealing influence to a prospective purchaser. The Bureau has been lending its influence to both the manufacturer and the operator with a view to securing a record of operations that will be a guide to the operator in the selection of a type of machine that may meet his local conditions. What seems to be most needed in the development of a satisfactory loading machine is close co-operation and sympathetic effort on the part of the designer and the practical mine operator, who will employ it when it is so perfected that there will be a real economy by its use.

A method adapted to the use of machinery for loading coal has been given some trials, and embraces the use of conveyors. This has required the development of the mine to suit the operation of the conveying machinery, and while this plan has not been employed to great extent, it seems to have possibilities at least under special conditions.

*Reports of Investigations, Serial No. 2300, December, 1921, by C. L. Colburn.

The general scheme is to install the conveyor along a long breast of coal, which is operated on the panel longwall retreating method, these breasts being made 300 to 500 feet long. The coal is usually undercut with a longwall machine and requires little explosive to break it down, and is then loaded onto the conveyor by manual labor. As in the case with mechanical loaders, this

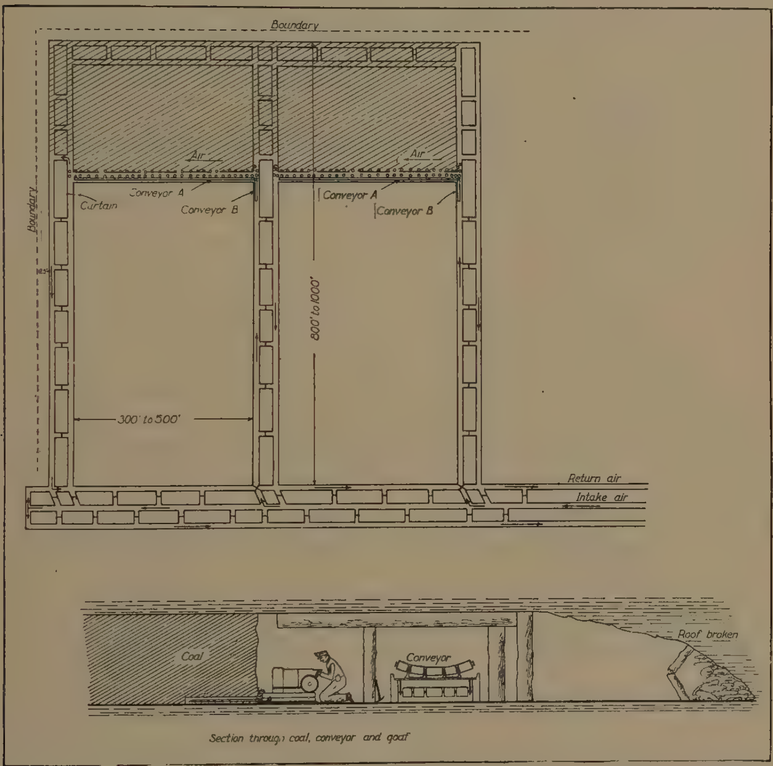


Fig. 14—Diagrammatic sketch, panel longwall method, using conveyors.

scheme requires special arrangement for the prompt movement of the mine cars. Such a method of mining and loading lends itself to coals having a flexible roof and being otherwise suitable for the longwall method—one of which is regularity of operation.

The general plan of operations by the use of conveyors at the working face is shown in Figure 14, and con-

sists of a longwall face of coal in a panel of the mine development. A line of mechanical conveyors is installed in sections along the breast of coal protected from falls of roof by two or more lines of props, and at places by cribs. It is essential to success, that the roof break in the goaf as the coal face recedes from the worked out portion of the panel, and thus relieve undue weight on the brow of the coal, otherwise the roof may shear at the coal face and cover up the line of conveyors. This method of mining has been confined principally to thin beds of coal, but an installation is reported as being under way in coal as thick as 5 feet, in which it is proposed to use conveyors exclusively for transporting the coal to the outside of the mine.

Summary and Conclusions

In bituminous mining there has been a decided improvement in the development of methods during the past 25 years. Changes in labor supply and the increasing cost of coal require a more general adoption of better methods.

The application of engineering knowledge has been of great advantage in securing a high recovery of coal, increase in safety and decrease in cost.

Concentration of work and supervision especially are in the interest of greater safety and of coal recovery.

More extensive introduction of machinery underground is to be anticipated, but it will be necessary to change mining methods in order to realize the full economy of the machinery.

Irregular working is one of the most serious handicaps to be met in improvement of practice and can only be expected to be eliminated in part.

From the standpoint of economy of operation, high recovery of coal, and the control of conditions that affect safety, the close adherence to a well-thought-out plan

adapted to the local conditions is a first obligation on operators and managers.

In many localities much coal is being lost beyond the possibility of future recovery and the time may come when the States will levy a tax penalty on coal that is unnecessarily left in mined-out areas.

Judge Gary: The next paper is on The Storage of Bituminous Coal, by Mr. H. H. Stoek, Professor of Mining Engineering, University of Illinois, Urbana, Illinois, and Mr. J. V. Freeman, Director, Coal and Coke Research Laboratory, United States Steel Corporation, Joliet, Illinois. The paper will be presented by Professor Stoek.

THE STORAGE OF BITUMINOUS COAL

H. H. Stoek

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AND

J. V. Freeman

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Some 3,000 years ago a certain ruler, named Joseph, during seven fat years built storehouses in which he stored grain that lasted him through a period of seven lean years of famine, thereby setting an excellent example to the industrial world for all time to come; but the example has, unfortunately, not been followed in connection with the storage of coal to anything like the extent it should have been.

With the coal resources of the United States so widespread and distributed through three-quarters of all the States, with ample coal resources located within a relatively short rail haul of most of the industrial centers of the United States, with a potential producing capacity in mines of at least 50 per cent more than the present requirements of the entire country, with many of the large users of coal owning their own coal mines and thus being independent of the ordinary competitive conditions of supply and demand, the question may fairly be asked, "Why store coal?"

From the standpoint of the user of coal, storage is an insurance measure and like all insurance, there is a wide divergence of opinion as to how much insurance should be carried and what is the best way to carry it. No one questions the necessity for fire insurance, and compensation insurance is no longer, in most States, a voluntary

matter. It is not without the bounds of possibility that insurance against a shut-down of industrial plants, due to lack of fuel, may become one of the prescriptions from somewhere, possibly from those sitting on Capitol Hill, although to date this is one of the few forms of regulations that seem to have been overlooked.

The iron and steel industry is interested in coal storage from a number of different standpoints. The industry consumes about one-fifth of the bituminous coal produced in the United States, that is about 100,000,000 tons per year, exclusive of subsidiary railroad requirements, and represents a yearly expenditure of at least half a billion dollars. Anything that has to do with this item of expense, which has steadily increased during the past few years, is worthy of the most careful consideration. This coal is used for coke and gas making, for steaming and for the generation of electric power. Many of the large steel companies also operate railroads in connection with the delivery of supplies through subsidiary railroad companies.

As large consumers of water, gas and electricity, either supplied from a public utility plant, or more generally through a steel company plant, steel companies are directly interested in the public utility situation. The steel industry is also interested in connection with the coal used for domestic purposes, not only through its interest in the living conditions for employees, but because in times of shortage the domestic user and public utility will be given preference if it comes to a matter of curtailment by any governmental distribution system.

During the stress period two years ago, the University of Illinois was compelled to shut down, even though it had an ample stock of coal for its own use, because there was a lack of coal for the boarding houses and restaurants upon which the student body of 8,000 was dependent. A large stockpile of coal of any industrial company is always looked upon with envious eyes in time of shortage and may be commandeered upon short notice, so that the

large industries should therefore be interested in developing a sentiment for the storage of coal by the domestic user.

The general reasons for the purchase of greater amounts of coal during the spring and summer months than are needed for current consumption are briefly as follows:

1. To assure the consumer an adequate and continuous supply which protects him against strikes, other labor disturbances and uncertain railroad deliveries.
2. To take advantage of water transportation and low freight rates.
3. To secure the advantages of low prices.
4. To equalize the prices on different sizes of coal.
5. To avoid the maintenance by the railroads of equipment that is used for only part of the year.
6. To maintain a uniform rate of production at the mines.

These reasons and advantages are axiomatic to the members of the American Iron and Steel Institute and do not need to be discussed. They all apply to the steel industry though of course in different degrees.

Even admitting that storage of coal as a stabilizing element in connection with the coal industry has been by some unduly stressed, all must admit its importance. The greater the uniformity in the production and transportation of coal, the less the amounts necessary to be kept in storage and the less the taxes and interest charges on the storage piles. Hence, while the insurance factor will always require a storage pile, a stabilizing of the mining and transportation of coal should materially decrease the amounts of coal necessary to be kept in storage at the steel plant and materially decrease the interest and tax charges upon coal kept even for a few months. This is a phase of the subject that has not been given the attention that it warrants and there is very little data available upon the subject.

Practicability of Coal Storage

That it is practicable to store coal is best shown by the experience of those who have tried it out. Every year hundreds of thousands of tons are stored along the Great Lakes for distribution through the Northwest. All of the by-product coke plants store large quantities and also many of the public utility companies and manufacturing concerns. To be sure, failures have been recorded, but an investigation of these failures has nearly always shown that in the storage the vital and fundamental principles of coal storage have been neglected. One of the largest and most successful storers of coal has been the Commonwealth Edison Company of Chicago. In a recent article Mr. John M. Glenn, Secretary, Illinois Manufacturers' Association, states that the Commonwealth Edison Company at the beginning of the recent coal strike had about 415,000 tons of bituminous coal in storage on the ground, 25,000 tons in transit and 30,000 tons at its stations and when the strike officially ended August 22nd, 170,000 tons were still in ground storage, 27,000 tons in transit and 30,000 tons at the stations. During the strike 845,000 tons of coal were burned. You may imagine the comfortable feeling of the officials of this company with such a coal pile reserve.

Disadvantages of Storage

If, therefore, coal storage is advisable and practicable, what are the disadvantages of it and why is it not more general? The objections usually offered may be summarized under two heads: financial considerations, and the physical and chemical changes in the stored coal.

That it costs to store coal goes without saying and this cost must be balanced against the insurance features. It is probable, however, that if storage practice can be stabilized and extended so that the benefits of it may extend to coal transporting railroads and producing

mines, stored coal may become self-supporting as a result of differential freight rates and cheaper production costs during the present slack seasons of mining.

The steel industry very generally, I believe, now considers the expenditures for better housing, sanitation and many other sociological measures, that were at first considered extravagances, to be good investments.

If, as is commonly assumed, storage of coal will prove of benefit to the coal producer, transportation company and user of the coal, any increased cost should be borne jointly by these three interests and it should not be expected that the user will pay for all of it. The producer must expect to compensate the user if storage by the latter permits a less mining cost, and, likewise, the railroad if it can haul coal more cheaply during the summer should expect to give a decreased freight rate. As one result of the Stabilization Conference held in New York in March, 1920, a bill was presented to Congress, but not passed, authorizing a differential freight rate on coal hauled for storage purposes during the summer months.

In connection with reduced railroad rates that should result from the storage of coal, Mr. W. L. Abbott, Chief Operating Engineer, Commonwealth Edison Company, recently has said:

"In my belief, we can get better rates from the railroads if we would give them a greater proportion of our business during the slack summer months. If during the six months of spring and summer we should ship enough coal to supply our demands during those months and enough more to tide us over the six months of fall and winter, the railroad companies would find it to their profit to make a reduction of 50 per cent in the freight rate in summer. No doubt they would at least find it to their advantage to establish a summer rate of 50 per cent of normal rate, provided they were permitted to charge in the winter 133 per cent of the normal rate, and if consumers could arrange to receive and store during the six low-rate months, one-half of the coal which they would

require in the winter time, they would have reduced their total freight charge 27 per cent, or, on a $1.85 freight rate, 50 cents a ton. From this, however, should be deducted the cost of handling into and out of storage half of their winter's supply, which might amount to 20 cents a ton on that portion handled, or a charge of 5 cents a ton on their whole year's supply, making their net saving 45 cents."

In the fall and winter months the railroads are moving the crops and the greater part of the consumption of coal. In April the movement of coal falls to a third of what it was during the winter months due every alternate year, of course, to a strike or shutdown. The amount transported shows substantial increases month by month until September, when the fall movement of domestic coal is at its height, thus the greatest tonnage is moved when the cost of moving freight per ton mile is considerably greater than during the summer months. For instance, in the summer it takes eight days for a coal car to make a round trip between Springfield, Illinois, and Chicago, while during the winter months it takes twice as long. Labor, motive power, wear and tear are all increased and equipment earns only half as much. It is unfortunate, from the railroad's standpoint, that it must handle the bulk of its coal tonnage during the fall and winter, while in the summer, due to lack of business, a large part of its coal car equipment stands idle on sidetracks. This condition applies particularly to Illinois, but in some sections as, for instance, western Pennsylvania, Ohio and West Virginia, where much of the coal is sent over the Lakes to the Northwest, the summer season is the busy one both for the mines and the railroads.

In addition to this saving, Mr. Abbott estimates a cost in mining of 75 cents per ton. The exact figures upon which this estimate is based are not given and this particular figure is, therefore, given only as an opinion of one prominent engineer as to the possibilities in the way

of saving as a direct result of more continuous working of the mines.

Figures as to the cost of storage are hard to obtain as few companies keep a storage account separate from the general cost for handling all of their coal. Moreover, there is no uniformity in the methods of keeping the coal accounts and too many of the costs published include only labor and materials, although the cost should include the following items:

1. Overhead.
2. Labor.
3. Supplies.
4. Depreciation of mechanical equipment.
5. Interest on investment.
6. Rental on land on which coal is stored.
7. Insurance on equipment.
8. Insurance on coal.
9. Taxes on coal in storage.
10. Decreased value of the coal, if any.

In 1918, the writers attempted to gather costs of storing and reclaiming coal under the above heads and the figures reported varied from 10 cents to 54 cents per ton with no certainty in most cases as to what items were included in the totals given. Another attempt to gather similar statistics during the past summer met with like results. At the present time we believe that a minimum of 25 cents per ton should be counted on as a charge against coal in storage and in many instances it is undoubtedly more.

To store 100,000 tons of coal in a pile of 40 feet high requires at least three acres of ground space without allowing room for tracks and operating machinery. Rental on this ground may be a material item. Storage of 100,000 tons in Chicago at present represents an investment in coal of about $500,000. Interest and taxes on this investment should be considered but usually are not.

The storage of from 5 to 10 per cent of the total output of anthracite at the upper Great Lake ports in order to take advantage of water transportation during the summer, and near the seaport and the mines, as a reserve supply, have increased summer buying for domestic use, which has been stimulated by a decreased price. This storage did much towards equalizing the monthly production of anthracite. Although the storage of anthracite and of bituminous coals are by no means parallel, and while there are problems and also certain difficulties

Fig. 1—Coal Storage, Gary Coke Plant, Illinois Steel Company, Gary, Ind.

that must be overcome in connection with bituminous coal storage that do not apply to anthracite, it is feasible to store bituminous coal in such large quantities as will provide relief for coal operators, mines and railroads by stimulating production during the summer months. The monthly fluctuations in coal production as given by Director George Otis Smith and F. G. Tryon of the United States Geological Survey, in a paper read before the American Institute of Mining and Metallurgical Engineers in March, 1920, are not as great as is often supposed, and a shifting of only 50,000,000 tons from winter

to summer would cause the production curve to be quite regular. This 10 per cent of the total production should be easily transferred from the winter to the summer months and be absorbed by the various industries that will be benefited.

Irregular working, in the form of idle days and short days due to lack of demand, shortage of railroad cars, labor trouble, etc., means, of course, increased cost of the coal produced during the working time, but this fact is very difficult for the general public, that buys the coal, to grasp. The late Francis S. Peabody testified before the Frelinghuysen Committee in 1918 that mining costs varied as much as 50c to 60c per ton from month to month, due to the difference in the number of hours that the mines worked. Irregular employment of the miners undoubtedly begets irregular habits and a disinclination to work full time even when there is an opportunity to do so.

As coal is by far the largest item in the freight hauled by the railroads, irregularity in the amount hauled in different months means excessive equipment and disorganization of schedules, as well as the increased cost of hauling during cold weather. The effect of irregularity on the consumer is, of course, increased cost of the coal as he must support the miner for the full year, even though he works only 200 days. He must compensate the operator for his excessive overhead and idle time items and must pay the railroads for extra equipment, etc.

This naturally raises the question "Where and by whom should coal be stored?" The obvious answer is "As near as possible and practicable to the point of actual consumption, so as to insure the user a steady supply, to avoid the extra cost and extra breakage incident to each rehandling, and also so as to best utilize transportation facilities." In connection with steel plants, the point of storage is nearly always near the coke oven plant or power plants, as there is usually ample storage space available; but it has been suggested by

some that even in the case of large steel companies in the same district a central coal storage ground might be established to supply several plants. This, however, does not seem to be a very practicable suggestion. In the congested city districts, the needed space for storage is too valuable for renting purposes and many of the large users of coal provide a storage supply on the outskirts of the city, or even outside the city limits, but within the

Fig. 2—Coal Storage, Gary Coke Plant, Illinois Steel Company, Gary, Ind.

range of suburban railroad service or even of motor truck hauling distance. One example of this is the Commonwealth Edison Company already referred to, which, in addition to the storage plants at each of its power houses within the city limits, keeps a supply of several hundred thousand tons just outside the city limits. Some of this coal has been in storage for at least 10 years and it is kept mostly for emergency purposes and not drawn on for current use. In regard to this storage Mr. Abbott

says, "I can guarantee to store coal so that there will be no fire hazard, or I can guarantee to store it so there will be a fire. Storing coals in lump is perfectly safe and feasible, it is the fine coal that results in spontaneous combustion."

The coal-mine operator is interested in storage as an operating proposition that will enable him to run his mine more days per week and per year than he is able to do under present conditions. The car supply at the mine during the early part is usually better than during the latter part of the week and by placing coal in storage, he can take advantage of any extra cars that may thus be on hand. The demand for the different sizes of coal varies with the seasons and by having a storage pile he is able to supply this demand to better advantage. With storage facilities he can also fill out a day even though the car supply may be short at the beginning or end of a day.

It does not help the coke plant and other industrial concerns short of coal to know that there is a supply in storage at a mine several hundred miles away, as the prime factor in shortage of coal at industrial centers has heretofore been due to lack of transportation facilities.

Physical and Chemical Changes in Stored Coal

The physical disadvantages of storage are due to breakage of coal from extra handling and from weathering on the outside of the pile. The relative amount of the coal affected by outside weathering depends, of course, on the size of the pile as the disintegration due to weathering does not extend any distance within the pile. This breakage is not material in coal to be used for coke making or for stokers, but may cause a material loss in domestic coal due to the lower price obtained for the smaller sizes.

Under the head of chemical changes are loss in heating power or the B.T.U. value, changes in the coking prop-

erties and by-products, and actual losses in coal through burning as a result of spontaneous combustion. A clear distinction should be made between heating in a coal pile and spontaneous combustion or actual ignition of the coal. Unfortunately, this distinction is not usually made in discussing the chemical effects upon coal in storage, and there is a fertile field for investigation as to the effects produced in coal by different degrees of heating in the pile below the point of actual spontaneous combus-

Fig. 3—General View of Works, Coke Works, American Steel and Wire Company, Cleveland, Ohio.

tion or ignition. The term "spontaneous combustion" is used too often to apply to heating to a low temperature below the ignition point.

There is a wide difference of opinion in regard to the decrease in heating value of stored coal and some of this is undoubtedly due to the failure to discriminate between a slight heating and actual combustion. There is a great prejudice on the part of many firemen against stored coal, much of which, like all prejudices, is not warranted. Experiments have shown that the heating value as ex-

pressed in B.T.U. is decreased very little by storage but it is possibly true that stored coal burns less freely than fresh coal. Exact data upon this point are not available although experiments to determine what losses there are, if any, are in progress at the University of Illinois and probably elsewhere. In coal stored under water, the deterioration is negligible. Undoubtedly some of the prejudice against stored coal is justifiable and is due to the fact that, in picking up coal from the storage pile with a clam shell bucket, dirt and rubbish are mixed with the coal, and it is not at all uncommon to have the report that more coal has been taken out of storage than was put into the storage pile. Naturally this increase is not of advantage to the fireman.

While some kinds of coal are more liable to heating and spontaneous combustion than others, it is not possible to say whether a certain coal will or will not heat or ignite spontaneously provided the conditions are favorable for spontaneous combustion. The evidence shows conclusively that all varieties of bituminous coal have been kept without firing and it is equally true that all varieties have fired under certain conditions. This does not mean that all coals are equally free from spontaneous combustion, as there is undoubtedly a difference in the storage quality of coals from different districts, but the evidence shows conclusively that it is not so much the kind of coal or the district that it comes from, as it is the size of the coal and the way in which it is handled. If investigation shows that coal from a certain district, or even from a given mine, has frequently fired, common sense suggests not placing such coal in storage if it can be avoided, and this has been recognized by the United States Navy which has a list of accepted mines from which coal may be purchased. Many believe that there are inherent qualities in certain coals that render them particularly liable to spontaneous combustion, but the evidence available at this time does not permit the coal

to be chosen for storage purposes on the basis of composition only.

There is an erroneous, misleading, but widespread opinion that the locality from which the coal comes determines whether or not it can be stored. One frequently hears such remarks as "Eastern coals (meaning those from Pennsylvania and West Virginia) can be easily stored, but Western coals (meaning those from Illinois and Indiana) cannot be stored and are much more liable

Fig. 4—Coal Storage Yard and Coal Bridge, Coke Works, American Steel and Wire Company, Cleveland, Ohio.

to spontaneous combustion." Both parts of this statement are too broad, for scientific research and the experience of those storing coal agree that while there are undoubtedly differences in different coals that affect their liability to spontaneous combustion and also to degradation, these differences are of less importance than the size of the coal stored, the care with which it has been prepared, and the way in which it is stored.

In the United States and England extended researches are in progress at the present time as to the exact chem-

ical composition of coals which may have a bearing upon this subject, but as yet nothing has been published that is of assistance in differentiating coals as to their liability to spontaneous combustion.

Time will not permit of a detailed discussion of the subject of spontaneous combustion in coal, but there is ample literature upon the subject and only a few of the generally accepted conclusions will be given together with some of the erroneous ideas that are still very generally held by large numbers of those having to do with the storage of coal. Spontaneous combustion is due to chemical and physical changes in bodies that are partly or mainly carbonaceous under the influence of atmospheric oxygen. This carbonaceous material and the iron pyrites in the coal by being oxidized generate heat and unless this heat is carried off by an adequate air supply passing over the substances that are undergoing oxidation that temperature will rise to the point of ignition of coal and spontaneous combustion will take place. If air could be totally excluded, there would be no self-heating and no combustion. If the principal factor in spontaneous combustion is due to the oxidation of the carbon in the coal, the greater the surface exposed to the air, that is, the finer the coal the greater is its liability to spontaneous combustion. Therefore, the greater the amount of fine coal and particularly the amount of dust, the greater the liability to spontaneous combustion. If coal can be screened to remove the fine portion the liability to spontaneous combustion is greatly reduced and in many cases entirely removed, but this is unfortunately often impracticable and particularly so in connection with the larger storage piles.

Sulphur in the coal in the form of pyrites, when it oxidizes, produces heat and assists in breaking up lumps of coal, and this not only helps to increase the temperature but also adds to the amount of fine coal. Sulphur is not the determining element in regard to spontaneous combustion of coal, as was thought to be the case for a

long time and is still very generally held by many who are not conversant with the literature on coal storage and the results of investigations upon the subiect. It is wise to select low sulphur coals, if procurable, but a low sulphur coal is not necessarily free from the danger of spontaneous combustion and high sulphur coals are not necessarily dangerous. If low sulphur coals were so much safer than high sulphur coals, there should be little trouble from heating in coal stored for coke oven uses, as such coals are chosen on account of their low sulphur content.

Fig. 5—Brown Hoist, Bethlehem Steel Company, Bethlehem, Pa.

The effect of moisture in connection with spontaneous combustion is a debated question and requires a great deal more investigation. The liability of coal to spontaneous combustion increases with temperature, that is to say, coal put into storage at 90° F. will oxidize and produce heat more readily than the same coal put into storage at a temperature of 60° F. Outside sources of heating, such as steam pipes, should not come into contact with the coal in storage and such extraneous material as oily waste should be kept out of the coal pile.

As to the effect of storage upon the coking properties

of coal, the answers received to a questionnaire sent out in 1917 show that the opinion is very general that storage decreases the coking properties of most coals but that coals vary widely in this respect. Even though ignition may not take place the temperature of the coal may rise to such an extent that valuable volatiles may be given off and the heating value of the coal, its gas making properties, or its value for making coke may be impaired.

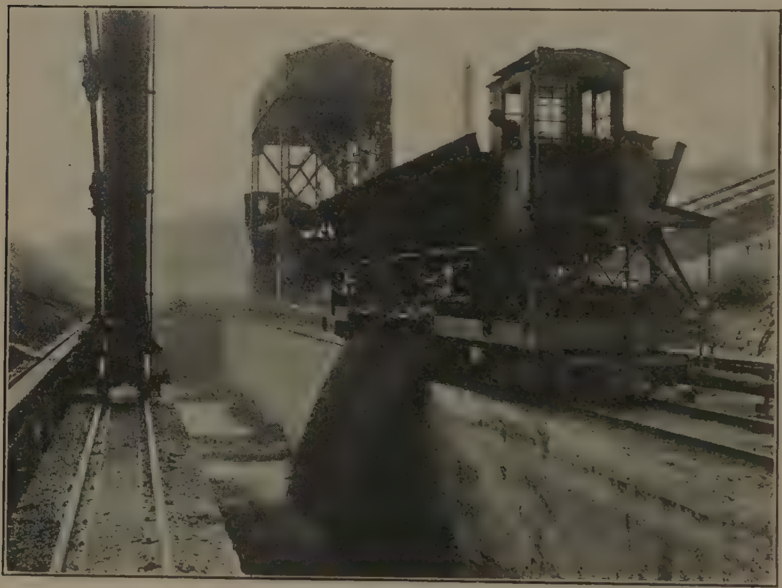

Fig. 6—Brown Hoist with 60-ton Transfer Car, Coke Plant, Bethlehem Steel Company, Bethlehem, Pa.

Authoritative data as to the effect of weathering upon the coking properties and the by-product yields are very few and the following results of an investigation by Mr. Freeman are of special interest. In 1914 at the Central Laboratory of the Illinois Steel Company in Joliet, Illinois, carloads of 50 tons each of the four coals listed below were placed in separate wooden bins each 20 feet long by 15 feet wide by 6 feet deep. The coals were placed directly on an earth floor and the tops of the piles were uncovered. The kinds of coal were the following:

1. Pocahontas No. 3 Seam Coal from Mine No. 12 of the United States Coal and Coke Company, Tug River District, McDowell County, West Virginia.

2. Coal from Gates Mine of the H. C. Frick Coke Company, Fayette County, Pennsylvania.

3. Coal from the Elkhorn Mine of the Consolidated Coal Company, Letcher County, Kentucky.

4. Coal from the Sygan Mine of the National Mining Company, Allegheny County, Pennsylvania.

Samples were taken weekly during the first six months and every two weeks during the second six months and analyzed with the following result after the coal had weathered for one year:

Summary of Laboratory Results

(Weathering Coal for One Year)

Kind of Coal	Loss of Ammonium Sulphate Per Net Ton of Coal Per Cent.	Loss of Net B. T. U. Per Cu. Ft. of Gas Per Cent.	Increase of Coke Yield Per Cent.	Increase of Hydrogen in Gas Per Cent.	Decrease of Methane in Gas Per Cent.
Pocahontas.....	15.12	2.17	0.36	2.85	2.80
Gates..........	3.81	2.40	0.96	5.18	6.03
Elkhorn........	2.35	4.05	1.98	5.72	5.51
Sygan..........	9.77	1.72	0.42	5.89	3.24

Except for the decrease in ammonium sulphate in the Pocahontas and Sygan coals the variations as shown by this table are not very marked, particularly when the difficulty of sampling the coal is considered and the conditions surrounding the determination in the laboratory of the other values listed.

Remarks on Quality of Coke Obtained from the One-Year Weathered Coals

At the expiration of the one-year weathering period, the following three types of coal were reloaded from storage bins into cars for transference to the regular coke

plant coal hoppers. After this, the regular course was pursued in handling, crushing and coking the coals.

Physical inspection of coke produced in the regular oven test is given as follows:

1. Coke produced from 100 per cent fresh Pocahontas had a slightly more open cell structure, and exhibited a more regular appearance and a brighter color than the weathered coal; while the stored coal seemed to produce a large coke, it was more cross-fractured and varied more in uniformity of size.

2. The coke from 100 per cent fresh Gates coal had

Fig. 7—Brown Hoist, National Tube Company, Lorain, Ohio.

a more open cell structure and more regular surfaces than the coke from stored coal. The stocked coke showed more attached sponge and was darker in color. The coke from stored coal again appeared to be larger, but was more cross-fractured than the fresh.

3. On the bench the coke from stored Elkhorn coal seemed to be a trifle larger than that obtained from fresh Elkhorn. Both cokes showed very open and regular cell structure. The coke from fresh coal was not as spongy and had smoother natural surfaces than the stored coal coke. The greatest noticeable difference between the cokes was the lack of good color and luster on the part of the coke from stored coal.

It was the unanimous opinion of operators, coke inspectors and chemists present at these tests, that it was a difficult matter to say that the coke obtained from the weathered coals was in any way particularly inferior to the coke obtained from the fresh coals. The same can also be said when comparing the test coke specimens produced in the laboratory carbonization process.

Fig. 8—Brown Hoist, Pittsburgh Steel Company, Alicia, Pa.

Suggested Research on Storage of Coal

1. Investigations should be carried on upon the effect of mixing coals in storage.

2. The development of a more easily applied method for detecting the heating in a coal pile.

3. The effect, if any, of organic sulphur in connection with spontaneous heating.

4. A method of storage more nearly like underwater storage where there is no danger of spontaneous combustion and little, if any, deterioration in the heating properties of the coal.

5. The effect of moisture in coal as increasing the hazards of spontaneous combustion.

Choice of a Storage System

In the choice of a storage system the following points should be considered:

1. The location, size, and topography of the available storage ground.

2. The capacity of the desired installation, that is, the amount of coal which it is desired to load and unload in a given time.

3. The cost of the plant.

4. The cost of maintenance.

5. The cost of operation.

6. The amount of breakage to be permitted in handling the coal.

7. The way in which the coal is received, in open or box cars, or in boats.

8. The length of time the coal must be kept in storage.

9. Climate: Underwater storage is impracticable for a part of the year in some of the colder sections of the country, such as Duluth.

The Requirements of an Ideal Plant Are:

1. Adequate ground area, so that several sizes and varieties of coal may be stored separately. Separation into sizes has not been considered so important for bituminous as for anthracite coal, but it is becoming more important because of the increasing attention being given to preparation of coal for domestic use, and because of the fact that danger of spontaneous combustion is decreased by keeping different sizes separate in storage.

2. Adequate facilities for rapidly and economically transferring coal from cars or from boats into storage.

3. Adequate facilities for rapidly and economically reclaiming the coal and for rapidly moving any part of the pile which shows evidences of taking fire.

4. Adequate track facilities, with gravity facilities, if possible, for handling cars.

5. Means for preventing undue breakage in handling.

Fig. 9—Brown Hoist, International Harvester Company, South Chicago, Ill.

6. Facilities for rescreening the stored coal to be used for domestic purposes, which, of course, increase the cost.

7. Adequate available water supply for putting out fires.

8. Low cost of installation, maintenance, and operation per ton of capacity. A storage plant is in operation very irregularly and costs are likely to be correspondingly higher because of the heavy fixed charges, especially interest and depreciation.

Few, if any, storage plants possess or require all these ideal conditions. In a coke plant, for instance, breakage need not be considered, except in connection with spontaneous combustion, since the coal is ground fine before being charged into the ovens. Storage facilities must, of course, be adapted to the various requirements and limitations of coal yards, power plants, railroad yards, boat docks, steel plants, and other establishments.

Fig. 10—Brown Hoist, River Furnace Company, Cleveland, Ohio.

Usually much of the storage must be done under conditions far from ideal, but the fact that the prevailing conditions must be accepted does not excuse the lack of forethought too often observable in connection with storage propositions. In fact, it might be said that the more favorable the conditions about the plant for storage the greater should be the foresight and care in planning for storage. Do not undertake to store coal until you are sure you know how to do it properly and safely.

Storage Appliances

Storage appliances vary from a wheelbarrow and shovel at a small boiler plant to the most elaborate types of movable bridges, conveying belts or a combination of

these two types, such as are used in most coke plants and in most cases where large amounts are required to be kept in storage, and particularly where the coal is moved frequently. The illustrations given herewith show some of the typical coal storage plants throughout the country, particularly those of large capacity, 100,000 tons and upwards.

Fig. 11—Belt Conveyor Bridge, Inland Steel Company, Indiana Harbor, Ind.

The Common Methods of Storage May Be Classified as Follows:

1. Pile storage from cars without a trestle.
2. Trestle storage.
3. Side-hill storage.
4. Locomotive crane storage.
5. Storage by ditchers.
6. Dragline storage.
7. Bin storage.
8. Portable conveyors.
9. Belt conveyors.
10. Bridge storage.
11. Underwater storage.

Methods of Piling

1. Coal should be so piled for storage that any part of the pile can be moved promptly if necessary.

2. Coal should be so piled that air may circulate freely through it and thus carry off any heat generated, or else so closely packed that air cannot enter the pile, i.e., underwater storage conditions should be approximated as nearly as possible.

Fig. 12—Lidgerwood Cableway, Winchester Repeating Arms Company, New Haven, Conn.

3. Stratification or segregation of fine and lump coal should be avoided, since an open stratum of coarse lumps provides passage for air to reach the fine coal, but not in sufficient quantity to keep down the temperature of the pile. Coal should be spread in horizontal layers and not dumped in conical piles, for in the latter case the fine coal stays in the center at the top of the pile and the lumps roll to the bottom.

4. The depth and area of storage piles will be determined largely by the storage space available and the mechanical appliances to be used. Other conditions being

equal, the deeper the pile and the greater its area the greater the difficulty in inspecting it, and in moving it quickly if necessary. Hence, a number of small piles, if practicable, are better than one large pile. Lack of space, however, usually prevents such spreading out of the coal. It is impossible to specify exact heights, as so much depends upon the kind of coal and upon local conditions.

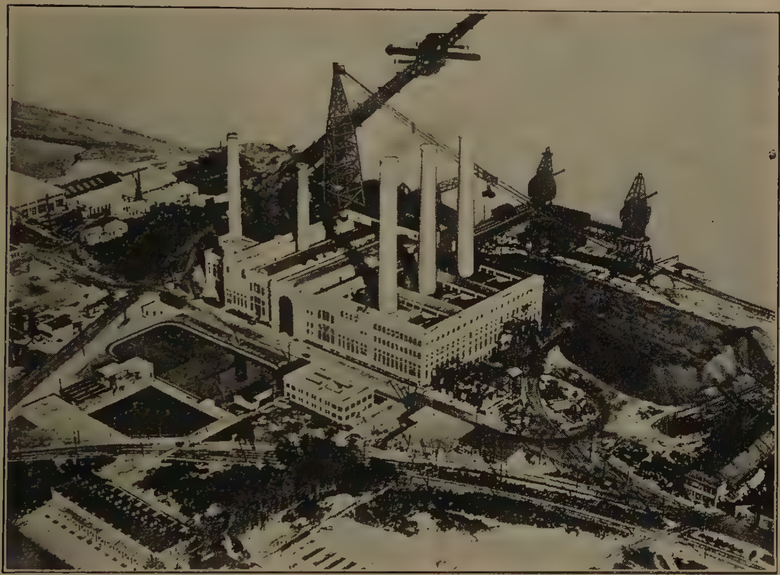

Fig. 13—Lidgerwood Cableway of Consolidated Gas and Electric and Power Company, Baltimore, Md.

5. The question is often asked: "How deep may coal be piled?" Piles five or six feet deep have taken fire and many piles fifty feet deep have not. Experiments in England, confirmed by experience in the United States, show that the highest temperature often occurs at a point five to ten feet below the top of the pile and that in general there is a gradual decrease in temperature downward and below this maximum point. In England, a standard depth at which temperatures are tested is seven feet be-

low the top. This depends to a considerable extent, however, upon the way in which the coal is piled, and although there are many instances of high piles that have not fired, the evidence shows that there are more fires in deep piles than in shallow, and this may be due to any one of the following reasons:

Air can circulate through a deep pile less readily and carry off the surface heat.

Fig. 14—Lidgerwood Cableway of Consolidated Gas and Electric and Power Company, Baltimore, Md.

With a deep pile there will usually be increased breakage and fine coal, and there is also greater difficulty in watching the pile and in detecting incipient fires.

As to the effect of the quantity of coal in a storage pile, the difficulty of storing and watching a large quantity and of moving it quickly may increase the fire hazard, but a large quantity is not of itself more dangerous than a small amount. In all cases the arrangement of the pile so that it can be easily reached by an appliance for moving the coal in case of necessity is of much greater im-

portance than the depth of the pile or the total amount in the pile.

The fundamental consideration where coal is piled by machinery is that there should be the least possible breakage and that segregation of the sizes may be avoided. The breakage will be very materially lessened if the clamshell bucket is lowered to a point just above the surface of the pile before the contents are dumped.

If possible, a place should be chosen that is dry and well drained; or, if not drained naturally, drains should be provided about the storage pile, not underneath, as a drain beneath a pile may admit air-currents to the pile sufficient to produce oxidation but not enough to keep down the temperature.

Coal should not be dumped on ground covered with ashes or refuse of any kind because, in addition to furnishing flues for the admission of an inadequate air supply to the coal pile, such refuse often contains material that will assist spontaneous combustion. Furthermore, it is likely to become mixed with the coal and, when it is reclaimed from storage, the value of the coal is thus depreciated. If possible, the ground should be cleared of vegetation and leveled off, so that the reclaiming of the coal may be done as easily as possible and so that dirt and refuse will not be taken up by the shovel or other devices used in reclaiming.

Judge Gary: The Present Status of the Electric Furnace in Refining Iron and Steel, by Mr. John A. Mathews, President, Crucible Steel Company of America, New York.

Mr. John A. Mathews: The committee thought that this time might be opportune for presenting something in the way of a resumé of the progress in electric smelting since its inception. Like the Judge, I prepared this paper on Sunday about three weeks ago, for want of other time.

THE PRESENT STATUS OF THE ELECTRIC FURNACE IN REFINING IRON AND STEEL

John A. Mathews

President, Crucible Steel Company of America, New York, N. Y.

It seems to have been generally overlooked by the steel trade that this year, 1922, marks the ter-centenary of iron making in the Western Hemisphere. In 1622, the first iron was made at Falling Creek, Virginia, and in the same year the plant was destroyed and the workmen massacred by the Indians. It is a far cry from charcoal hearths and forges to the consideration of the electric furnace—the latest development in steel making processes.

The earliest literature of electric melting of iron and steel dates back but a score of years and was provided by the inventors of various furnace types. It is characterized by the enthusiastic optimism of the inventor and on that account may not have been considered very seriously by conservative, practical steel men. Their confidence in electric furnaces may not have been greatly increased during the next few years by the writings (including my own) of those who made the earliest installations. They may have felt that there was something of the child-with-a-new-toy air about them, and that both inventors and early users were overstating the case and that time and further experience might change matters. The war needs stirred some of the doubting Thomases to action and furnaces were installed in great numbers, particularly in the years 1917 and 1918. So rapid was the introduction of electric furnaces at this time that I felt constrained to utter a word of caution in a previous paper to this Institute* when I said: "We will pass

*The Electric Furnace in Steel Manufacture, Yearbook, American Iron and Steel Institute, 1916, p. 73 (May, 1916).

through a period of reaction and dissatisfaction with electric products while many of the new furnaces are in the experimental stage."

This opinion was based upon the fear that furnaces could be built faster than skilled operators could be trained. I now feel that my fears were justified by the experiences of the war period, for much electric furnace product was not what it should have been, and possibly not as good as much of the open-hearth product produced during the same period. I have always discouraged the idea that the electric furnace was a fool-proof and automatic process for making superior steel by those unskilled in steel making.

I believe now that the period of disaffection is past and that the sixteen years of experience, since the first electric furnace was installed in America, at the Halcomb Steel Company, have been sufficient to afford a sounder basis of judgment than may have been afforded by the earlier literature already mentioned. There are now nearly 1,000 electric furnaces in America and Europe, not quite half of them in the United States and Canada. Constant interest in these developments from the beginning leads me to feel that the pioneer writers were not overenthusiastic and that their claims and predictions have, in general, been fulfilled.

It will surprise many of you to know that Italy has about 180 electric furnaces for steel melting, that 27 of them are from 15 to 25 tons capacity, and in 1921 her tonnage of electric steel was second only to that of the United States, and reached a new high mark for that country. The annual productive capacity there is about 1,000,000 tons, and Doctor Giolitti recently told me that some of these furnaces were operating at unusually high speed and with great economy of electrode consumption, as low as 6½ pounds per ton for cold melting. For installed capacity, Italy ranks ahead of Germany, England and France, and second only to the United States.

The rapidity with which electric furnaces have been installed within the last decade all over the world calls for some analysis as to cause. After ten or twelve years of invention and pioneering there were about 125 furnaces in the world in 1912. At this time, Germany led with nearly one-third of the total number. Today, as nearly as may be estimated, there are 1,000 furnaces, 388 of them being in the United States according to the Iron Age figures for January 1, 1922. Accurate statistics have been extremely difficult to secure during late years, but according to Doctor Richard Amberg* there are 65 furnaces in Germany engaged in the manufacture of ingots, with a yearly productive capacity of 430,000 tons and an unknown number of furnaces making steel castings with a capacity estimated at 300,000 tons per annum. I think we may estimate the total number of electric furnaces in Germany as about 100 to 110.

The reasons for the world-wide expansion of electric steel making are three:

(1). Cheapening of wholesale power rates, due to hydro-electric and improved steam plant developments. Thus it is now commercial to use electricity for melting, whereas the original promoters of arc furnaces felt that their use would be of necessity confined to refining of metal premelted by the older processes.

(2). The extreme flexibility and adaptability of electric furnaces to a wide range of uses. It has been shown by experience that they may be successfully used for melting cold charges or refining liquid charges, for making ingots or castings, and for melting ferro-alloys. They may be used alone, or in conjunction with the Bessemer or open-hearth, or both. They may be operated acid or basic. They may be used in conjunction with the blast furnace or cupola for making grey-iron, malleable and semi-steel castings. For foundry use particularly,

*Electric Furnaces in the Iron and Steel Industry, Helios, Vol. 28, p. 169, for April, 1922.

the small units are advantageous for making frequent small heats of steel or iron castings.

The most popular size of electric furnace in this country is of six gross tons capacity, but furnaces from one-half ton to forty tons capacity have proven equally successful. In furnaces of six tons, or a little larger, hand charging is general, but in the larger sizes either mechanical charging of cold materials or the use of hot metal charges is usual. Duplexing of open-hearth steel is practiced in many of the larger units, while triplexing is done at the great installation at the Illinois Steel Company as described at the Institute a few years ago by Mr. T. W. Robinson.*

All of the manifold methods of operation are possible with the use of arc furnaces, which are by far the most frequently used, here and abroad. Of the different types of arc furnaces in the United States nearly one-half are of the Heroult type and considerably more than one-half of the productive capacity is represented by them.

The electric furnace has small possibilities in this country for the manufacture of pig-iron from the ore, but during the war period several furnaces were used to make so-called synthetic pig-iron from turnings and borings and other light scrap, in the United States, Canada and France. In Sweden, Norway and Italy, where metallurgical fuel is very dear and electricity is cheap, electric smelting of ores is an established industry. The world's production for 1921 is placed at 377,900 tons, and most of you will recall that the year 1921 was not a good year for high records.

(3). Quality of products. A new process to succeed must be cheaper in operation or produce a better quality. The cost of electric steel is rarely lower than open-hearth and never lower than Bessemer and therefore its success is presumably due to its producing a generally superior product. Of course there are especially favored localities

*The Tirplex Process of Producing Electric Steel at South Chicago, Yearbook, American Iron and Steel Institute, 1918, p. 115.

or peculiar market conditions which warrant the installation of small electric furnaces where open-hearth and Bessemer installations would be out of the question. In the same localities and markets electric furnaces do operate successfully alongside of large tonnage plants and under such conditions quality must be the principal reason for success rather than low cost.

It is quite obvious that this country has not installed 1,500,000 tons of productive capacity to compete with the present crucible capacity of one-tenth that volume. In an address several years ago, I said, "It is seldom that a process is discovered that cannot be improved upon. Crucible steel is an exception to this rule. This earliest process makes the best steel and has never been surpassed." The superior lasting qualities of German guns was often ascribed to the use of molybdenum, zirconium, uranium or other strange alloys, but my own idea is that the use of clean, well-melted crucible or electric steel is a more probable explanation. Crucible steel was employed for many submarine crankshafts, and apparently the Germans recognize that when fabricating and machining costs are far in excess of material cost, and where dependability is a vital necessity, it is a poor policy to save at the spigot and let out at the bung-hole. Quality depends upon the selection of raw materials, the process of melting and subsequent care in forging and heat treating. The electric furnace provides a reducing atmosphere in which sulphur is readily removed and with it goes one of the generally recognized inclusions, manganese sulphide, and the same condition serves to eliminate oxides.

The electric furnace, therefore, is a potential source of clean steel which is more highly appreciated than formerly, and the electric product is opportune to meet the new and exacting requirements for ordnance, automobiles and aeroplanes, and other devices in which alternating stresses are very severe. The importance of clean steel has been observed in the course of extensive investi-

gations of the fatigue of metals under the direction of Professor H. F. Moore. It is not too much to expect that the higher the elastic or proportional limit resulting from heat treatment, the more serious would become defects such as non-metallic inclusions and seams in parts made from inferior steel. Doctor McCance confirms this in stating that fatigue failure under repeated stress is a progressive failure, starting in all cases in some defect or irregularity either of internal structure or external surface.

By way of illustrating the freedom from inclusions in electric steel, I might mention the result of actual count of hairlines, due to inclusions, in the ground surface of steel to the same chemical specification—a chrome-nickel steel for aeroplane crankshafts. As the result of tests on several heats of this steel by the basic, and acid open-hearth and basic electric process, the average count ran in the ratio of 8 to 4 to 1, and the hairlines in the electric steel were much shorter than in the steel of open-hearth manufacture. Another illustration from my own experience may be convincing. In one of the races at the Indianapolis Speedway a few years ago, about one-half of the cars starting did not finish because of failure of vital parts. The following year nine or ten cars, which I knew contained our electric furnace product in their important parts, all finished the race without mishap, and included the winning car. A practical demonstration of this kind is more eloquent than columns of figures of laboratory tests. The recent paper by W. J. Priestley* outlines the splendid results of electric furnace ordnance steels made at Charleston, W. Va., in the largest furnaces in the United States. He shows that the results are due to clean steel and freedom from oxides, sulphur and phosphorus. These results show that large units, with proper handling, can produce very high quality steel, and we see no reason, now that

*Effect of Sulphur and Oxides in Ordnance Steel, Transactions, American Institute of Mining and Metallurgical Engineers, Vol. LXVII, p. 317 (1922).

larger electrodes can be made of dependable quality, why a sixty or eighty-ton furnace cannot be expected to give relatively as satisfactory results. The electric steel rail is still a desired possibility. The increased demands made upon materials of construction call for new methods for meeting those demands. As I stated here six years ago, the electric furnace was opportunely invented to meet a new demand rather than to replace an old process.

It would be mere repetition to restate here the various types of furnaces, such as arc, induction, radiation, etc. They have been described in books and technical magazines and we need only observe in passing that there have been no new principles of heating employed since the first few years—with the possible exception of Doctor Northrup's high frequency induction furnace which has not thus far been successfully employed in units of commercial size in the steel industry. Of mechanical and electrical refinements there have been many, all in the nature of improvements in regulation and economy. Among these may be mentioned two of American origin, J. A. Seede's automatic electrode regulator, and E. T. Moore's peak-load regulator. The principle of dual, or rather multiple, voltages was embodied in our original installation in 1906, but its metallurgical significance was not so apparent as it was later when we installed a process employing a 220 volt arc and with considerable difficulty succeeded in persuading the inventor that provision for a lower voltage for use during the refining period must be provided. The desirability of relatively high voltage for melting and low voltage for refining is now generally recognized. Many improvements have been made as the shortcomings of the earlier furnaces appeared, such as well-fitting doors, water-cooled arches, better electrodes and holders and economizers to cut down oxidation and waste of the electrode. In my own experience I have seen electrode costs per ton of product as high as $8.00

gradually decline to 35 cents. This was in a furnace refining molten charges.

The electric furnace is also a recognized factor in melting non-ferrous alloys, such as brass and Monel metal, as well as special alloys such as "Nichrome," "Rezistal," "Stellite," stainless steel, manganese steel and high-speed steels, besides an endless variety of the simpler alloy and carbon steels from the mildest to the hardest tempers. As stated earlier in this paper, its astonishing flexibility—versatility, we might call it—has attracted the attention of the metallurgical world in almost every branch of smelting, melting, refining, heating and even baking metals. To those of us who have watched its growth from the start, it seemed very slow in achieving the recognition we felt must inevitably come to it, but at last our early confidence has been confirmed in every steel-making country, because its products have fulfilled almost every expectation in every field wherein it has been thoroughly tried. The present success is due not only to the original inventors of the basic processes but also to the active co-operation of the great manufacturers of electrical equipment, furnace designers and builders, makers of refractories and electrodes and a group of earnest metallurgists in many individual plants who have studied every detail of operation.

When users acquire a full appreciation of what clean sound steel means in terms of national efficiency, safety and economy we shall see more rapid growth than has as yet been seen. Its usefulness to engineering and industry has just begun.

Judge Gary: Gentlemen, wouldn't you like to hear one of the papers that is on the program for the afternoon now, before luncheon? Or would you prefer to postpone it? We have a pretty long program this afternoon. What is your pleasure? If Mr. Entwisle is here I will call upon him now.

THE ECONOMIC IMPORTANCE OF THE POWER PLANT IN THE STEEL INDUSTRY

E. F. Entwisle

Assistant General Manager, Steelton Plant, Bethlehem Steel Company, Steelton, Pa.

From the inception of the human race, its development has been dependent on its knowledge of and ability to use power. The first manifestation of power was in man's own labor in caring for himself, then in using his power in making others work for him, then the gradually increasing realization that the blowing of the wind, the flow of water, the heat of the fire—all could be used in ways that outdistanced human effort and pointed the way to still greater possibilities of accumulated power. Civilization has progressed as sources and control of power have progressed and today we find virtually every line of human endeavor absolutely dependent on some kind of power not contained within the individual himself, every industry with power the very mainspring of its existence, and in innumerable cases furnished from a source over which the industry itself has no direct control.

From the beginning, the steel industry has had to depend on its own organization for its power, first in human effort in collecting its materials for reduction by natural combustion, then by further human effort applied to the bellows of the Catalan forge, then by the application of water power, by the steam engine and the combustion of natural fuel for steam generation. Afterwards followed the first crude efforts at utilization of waste gases in boilers and blast heating, working up finally to the direct use of the gas in the internal combustion engine, so that with the gradual development

of the industry there has been a parallel development in the industry's own power plants.

This has been true of necessity, for at the outset there were no adequate sources of, or means of transporting to the plant, the large quantities of power required, and long before any knowledge of electrical generation and transmission, it was recognized that the sources of power in the industry itself necessitated their utilization at the plant, so that we have today in every steel works a power plant, frequently in many units, generating in all of its several phases most of the power required to carry on the various operations from raw materials to finished steel products.

During comparatively recent years tremendous development has been made in the size, reliability and control of electrical apparatus for steel plant service and in the generation and transmission of the power required for its operation. Its almost innumerable applications need no recapitulation here, but they have been so general in character and large in total that in many cases the development of the plant's own power supply has not kept pace either in economy or size with the peak power demand, so that electric current frequently must be purchased to take care of these maximum load periods. It is only natural to expect that still further applications of power, both electric and steam, will be made in the ever constant development of the steel industry so that its power plant will ever become increasingly important.

How large a factor any one item is in steel manufacture is judged mainly by its percentage of the cost of the finished product. Knowledge of operating costs is essential to economic operation, and the steel plant cost sheets of the present day furnish the executive with the detailed information that enables him to analyze production costs. Every item, raw materials, labor repairs, transportation, etc., and their relative importance to each other for various products, is constantly before

him, and his mind is always concerned in cost betterment, either through rendering labor more efficient, through price reductions, substitution of less expensive or of better materials, or through more economical use of the materials available. Unfortunately, power does not appear on our cost sheets as a single total item and we are apt to think of power costs only to the extent that they do appear as separate items of steam, electricity, water and air, not always remembering that power is the total of all of these, plus the additional power costs that are necessarily included in our cost sheet figures, in raw materials for their handling, in partly worked materials, power for shops appearing as repairs, and many other auxiliary operations.

The result is that the true cost of power is not generally fully appreciated, total power cost being defined as the cost of producing or purchasing all the energy for generating steam, electricity and blast furnace blowing. In such a cost, waste heat must be accorded a value commensurate with the value of the fuel that would have to replace it if the waste heat were not available. While it is true that the value placed on such waste heat is returned as a credit to the cost of the producing department, its real value must be set down as an item of power expense in order to fully appreciate how large an item power actually is in production costs and for a proper realization of the importance of its economic use. However, it is also important to know what portion of power costs occurs from such waste gas and heat charges, and it is advisable that these charges be so accumulated that their effect on costs can be properly judged.

The data submitted has been taken from the cost records of three of Bethlehem's steel plants and covers the period from January 1, 1920, to August 1, 1922. It is felt that this period is fairly representative of modern practice, 1920 being a year of good production, but with many war time prices and practices still continuing, 1921 being a year of low production and best

possible economy, and 1922 being a period of increasing production with a continuance of improvement in the economies of 1921.

	Including value of By-Product Gas and Waste Heat		Not including any value for By-Product Gas and Waste Heat and with Total Power Consumption figured at Plant producing cost.	
	A	B	A	B
1. Ratio of total power cost to delivered cost of all coal for coking	.82	.60	.60	.28
2. Ratio of total power cost to delivered cost of all gas, coal and oil	1.67	.64	1.22	.30
3. Ratio of total power cost to delivered cost of all ore	.65	.60	.48	.28
4. Ratio of total power cost to delivered cost of all limestone	5.35	2.40	3.90	1.10
5. Ratio of total power cost to delivered cost of all alloys	2.45	2.16	1.80	1.00
6. Ratio of total power cost to delivered cost of all refractories	2.70	2.98	2.00	1.40
7. Ratio of total power cost to total ingot cost	.138	.142	.101	.065
8. Ratio of total power cost to total plant pay roll	.255	.230	.187	.106
9. Ratio of total power cost to sales value of all finished products	.071	.080	.052	.037
10. Horse power hours consumed per ton of shipments	286	242	286	242
11. Kilowatt hours (including equivalent of blast furnace blowing) consumed per ton of shipments	256	516	256	516
12. Per cent. of blast furnaces blown by gas engines	100	100	100	100
13. Per cent. of Item 10 generated by waste products	39	68	39	68
14. Per cent. of Item 11 generated by blast furnace gas	78	72	....	....

It is not necessary to repeat here the individual power consumptions for various products, as we are interested primarily in accumulated power usage and cost. The above tabulation shows the ratio of the cost of total power generation to the costs of some of the principal and more familiar items entering into production costs. From these figures have been eliminated all the effects of such pig iron and coke as were manufactured for

shipment to outside customers, so that the data applies generally to any steel plant, the operation of which extends from coke ovens to finished steel products. In the first set of figures, blast furnace and coke oven gas and waste heat are charged to costs at full value. In the second block, all charges for such waste heat products have been eliminated and all power purchased is assumed to have cost the same as the power generated at the plant.

The importance of power as an item in production costs is sufficiently apparent from the preceding tabulation. Any single cost item that, stripped of all credits, reaches the proportion of nearly one-fifth of the total plant pay roll, or five and one-half per cent of the total sales value of all manufactured products, or twice the cost of all refractories, commands attention. How to reduce it, and the extent to which it can be reduced, constitute the real economic question. Every plant is a problem in itself, and no definite formula can be laid down that is applicable to all. Different kinds of products, different degrees of finish, different seasonal demands and many other variables are considerations that necessarily must be taken into account in determining how much and in what manner power shall be generated. It is undoubtedly true, however, that comparatively few plants are in the position where their total power costs cannot be reduced and at the same time show a good return on the expenditures required to make the reduction.

In general there are three points of attack on the problem after the cost analysis has been made; first, on the prime movers of mill and auxiliary drives; second, on the electric generating and blast furnace blowing plants; and third, on the steam plants.

Prime Movers for Main Drives and Auxiliaries

For new installations there is little room for argument against electrification as showing the greatest

economy. For existing steam-driven units practically every case will show a fair return on the investment by the substitution of electric drive, including the generating equipment. Some improvement can often be shown by the substitution of more economical types of steam drives, but aside from other considerations, it is obvious that the tremendous handicap of the miles of steam piping required for a steam operated steel plant imposes a burden on the steam drive which it cannot carry in competition with the electric drive.

The Electric Generating and Blast Furnace Blowing Plants

It is not contemplated in this paper to discuss the relative merits of the types of drive for this service. Sufficient to say that, in general, steel works have not taken full advantage of the economies possible. The power plants are often scattered in a number of separate installations and the overall efficiency of all power generation is not nearly the possible maximum. Usually the maximum operating load can be carried only by putting uneconomical units into operation, or by purchasing power from an outside source.

Steam Plants

Here can usually be effected the greatest economies and greatest savings. Steam plants are even more scattered than the electric generating plants. They are nearly always old and in small capacity units. It is probably safe to state that eighty per cent of steel works blast furnace gas fired boiler plants have no legitimate excuse for existence, and many of the coal burning plants are but little better. Steam lines should be eliminated wherever possible, and where they must exist, should have the fullest protection and attention to minimize condensation and leakage losses.

Keeping these three general points in mind it is interesting to return momentarily to the tabulated figures, particularly items 7 to 14, inclusive, as they illustrate to some extent the possibilities referred to.

A is the average of plants in which power requirements are about evenly divided between steam and electricity, and B is a plant which is, primarily, motor driven. While the nature of the products from plant B requires nearly twice the quantity of power per ton than do the products from A, B's power bill per ton is scarcely greater than A's, due to its more extensive recovery of power, proportionally, from its by-product gas and waste heat, and in spite of the fact that 28 per cent of its total electric power must be purchased at a unit cost of about four times its own generating cost, all of its own power being generated by gas engines. Plants A purchase 14 per cent of their electric power consumption. Improvements now under way at B will eliminate this excess burden, and a truer comparison of the accomplishment possible may be seen in the second block of figures, in which gas and waste heat charges have been eliminated and the power now being purchased figured at plant producing costs.

Further reductions in this plant's power costs may be made through the replacement of its existing boiler plants, and it is safe to say that this plant, or any one similar in equipment and power requirements, can reduce its total power bill, eliminating all charges for by-product gas and waste heat, to about 5½ per cent of its total ingot cost.

Returning to the general question of economic importance of the steel works power plant, there are a number of still unmentioned items that must not be overlooked. The investment necessary to accomplish the savings that are shown to be possible by such a detailed analysis is very often a large one and very often the amount is so large that the same investment in added steel capacity, or a different line of product, will yield

a larger return than will the power plant. Such a condition very often occurs, and where expenditures must be limited, the power plants have suffered in consequence. It must be borne in mind, however, that every plant addition increases the power plant's responsibility, and while the return may not be of the highest, it is sufficiently attractive to warrant the expenditure, and economically the right thing to do.

The power plant is linked economically with the utilization at highest efficiency of all the by-products of the industry and the plant that strives only to utilize sufficient of its energy producing by-products to carry its own power load is looking backward, not forward. Electric power has become of such tremendous importance to the every-day life of our country and its uses are constantly multiplying to such an extent that probably none of us fully realize the power demands of tomorrow. Our country's general system of power generation from coal mine to delivered power has an inefficiency that cannot indefinitely be tolerated, and we are undoubtedly not far from the day of the super-power transmission system, possibly under public service control similar to our rail transportation systems, and under which no industry with power producing by-products may escape the responsibility of contributing them to the general power system. Such an institution will ultimately result in economies to all industry, in reduced cost of power, and to the steel plant particularly, in solving the problem of the best means of supplying the widely separated peaks in both directions, of power demands and supply. Public interest in smoke prevention simply as a convenience has forced economy on many an industry, and the power situation of today offers a similar opportunity but with the additional weight of public necessity rather than mere convenience.

We cannot help but realize that steel plant operation cannot be, and is not, carried on under the wasteful methods that were common practice not so many years ago.

We acknowledge our responsibility in the happiness and welfare of our employees, we acknowledge our responsibility in the economic structure of our immediate communities and of the country, and we cannot be blind to the fact that the not far distant future will impose on us, and rightfully, the problem of converting at highest efficiency all of our waste products into power, to the end that all industry may be benefited by the surplus power thus made available and protected by the resulting conservation of our natural fuel supply.

JUDGE GARY: There is to be a five minute discussion of this paper by Mr. Collins of the Illinois Steel Company. We will have that now if he is here.

Discussion by F. L. COLLINS

Electrical Department, Gary Works, Illinois Steel Company, Gary, Ind.

Mr. Entwisle has pointed out that in the early days of the steel industry, "there were no adequate sources of, or means of transporting to the plant, the large quantities of power required, and long before any knowledge of electrical generation and transmission, it was recognized that the sources of power in the industry itself necessitated their utilization at the plant," and in the latter part of his article he states that, "the power plant is linked with the utilization at highest efficiency of all the by-products of the industry, and the plant that strives only to utilize sufficient of its energy producing by-products to carry its own load is looking backward, not forward." I agree with Mr. Entwisle that in most steel plants many improvements in economy of power generation are possible, thus liberating for manufacturing or public use great quantities of power which are at present a total loss. The sources of energy in the steel industry, their utilization and conservation constitute a subject which deserves the most intensive study on

the part of every person connected with the power system or management of the plant.

Sources of Energy

In the manufacture of steel we have the following by-products which may be utilized as sources of power:

(1)—Coke oven gas,
(2)—Coke breeze,
(3)—Tar,
(4)—Waste heat from open-hearth furnaces,
(5)—Blast furnace gas.

Practically all of the surplus coke oven gas can be used in reheating furnaces, in soaking pits, and at open-hearth furnaces in conjunction with the burning of tar. In the development of steam used on the plant for various purposes, coke oven gas can be used very efficiently. It can also be used at the blast furnace boilers in case of an emergency, or the occurence of some abnormal condition which causes a shortage of blast furnace gas. These are the most economical ways of using this by-product.

Coke breeze is another important source for the generation of power in many modern steel plants. This energy must first be converted into steam, which can be used in the turbine for the manufacture of electric power, directly in mill engines, or in by-product recovery in the coke plants.

All surplus tar from the manufacture of coke can be very efficiently used in steel-making in the open-hearth, or in reheating furnaces at the mills. Tar can also be used in making steam where an emergency supply of heat energy is required on a moment's notice to meet some extraordinary condition.

In recent years much of the waste heat from the open-hearth furnaces has been recovered in the form of steam to be used in making gas at the open-hearth or mill gas producers, to drive rolling mill engines, or to

supply power for presses and quick-acting shears, and also in generating electric power. All furnaces which give off unused heat to any extent should be equipped with waste heat boilers.

We now come to blast furnace gas which offers the best and most efficient source of electric power in the steel industry. This is due to its constant supply, uniform quality, the ease with which it is handled and the great developments made in the conversion of this form of energy into electric power. The big fluctuations in load in a steel plant can be met very quickly by the gas-driven unit. The curves shown below (see Fig. 1) will indicate how closely the available generating capacity at the switchboard can be kept to the load requirements. Although these gas-driven units are small in capacity compared to the large turbines, the ease with which units may be put on and taken off enable the operator to follow the load requirement quickly. On most modern plants the greater proportion of this gas not used in blowing engines is utilized to produce electricity.

Taking all of the heat energy consumed for the generation of steam used on the plant at Gary Works, the use of by-product energy is so well balanced that only approximately 1.7 per cent of the fuel used is supplied directly by coal. This coal is used entirely for pilot fires in the blast furnace boiler plant.

The following tabulation will give an idea of the proportion in which these by-products have been utilized in generation of steam throughout the plant:

Waste heat	43.0%
Blast furnace gas	28.0%
Coke breeze	23.0%
Tar	1.3%
Coke oven gas	3.0%
Coal	1.7%

There are many reasons why every large steel plant should have a power plant for the development of power, aside from the saving in fuel, which is vitally important in itself. It is not hard to realize, and could be shown

by figures, that all of these sources of energy can be most efficiently utilized in the manufacture of power

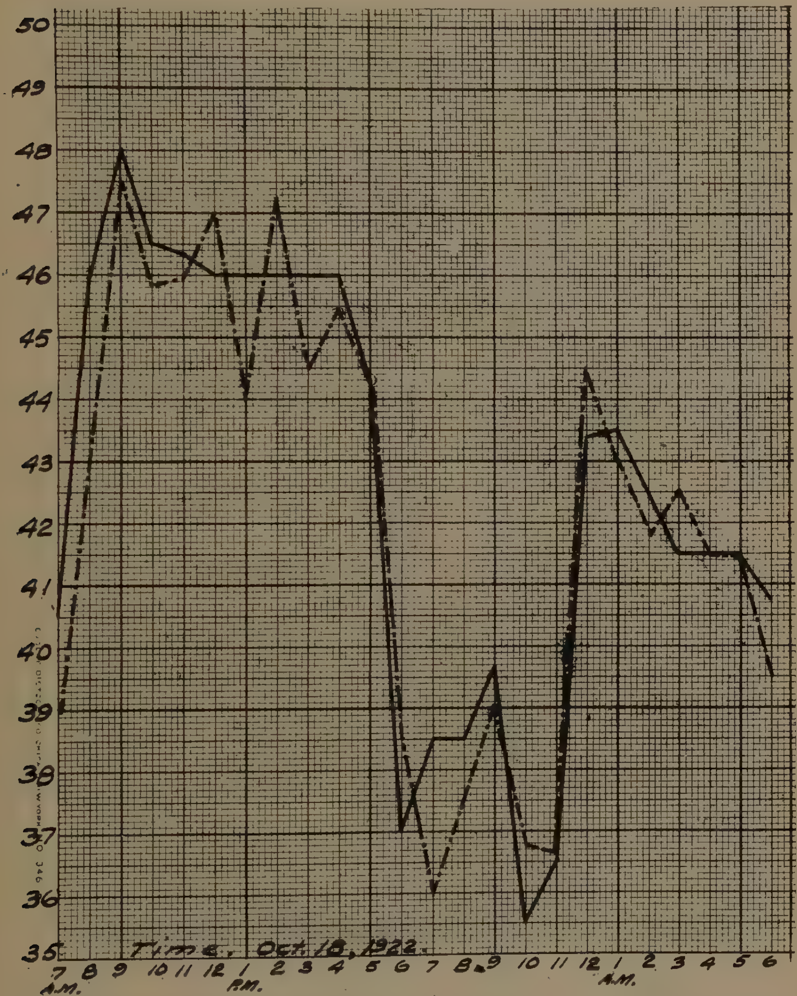

Fig. 1—Curves showing relation of power capacity on bus to power generated by gas engines. Solid line = Power available on bus. Broken line = Kilowatt-hours generated. Numerals on vertical coordinates represent thousand kilowatt-hours.

close to its source. Steam can not be carried to any great distance without serious energy loss. Maintenance of steam lines is a costly item. Neither would it be very

practical to pipe blast furnace gas to any considerable distance, due to the large and expensive piping that would be required.

Within the plant power system, a number of principles should be carried out to obtain greater efficiency and reliability of service. All of the economies in the development and use of power can not be made at the power house. It does very little good to have a highly efficient power plant if throughout the mills the power is not delivered and utilized with the highest efficiency and without interruption.

To protect the system from atmospheric disturbances and insulator failures due to many causes, all feeders to the separate mills should be three-phase cable distribution, placed underground, all protected by high voltage and high-frequency absorbers. This is extremely important in maintaining uninterrupted service. As far as possible all power should be supplied directly to large mill drives and other equipment at the generated voltage, thus eliminating transformer losses.

Another instance of conservation of energy is in the elimination of conversion losses by the use of alternating instead of direct current for all small mill motors. As an illustration of this, our merchant mills, which have a capacity of 130,000 tons of finished product per month, are almost entirely operated by alternating current. This effects a saving of about 16 per cent of the power that would be required if direct current motors were used. The only transmission losses that occur with the alternating current system are about 2 per cent for transformers and less than 2 per cent for feeders.

Reliability of power service is one of the most important economic factors in the steel industry. Every known means should be used to secure this reliability. We all know how important it is to provide for an uninterrupted water supply at the blast furnace, coke plant, open-hearth and reheating furnaces throughout the mills. A loss of water, or even a shortage, may

cause many thousands of dollars in damage to equipment in a very short time, beside endangering the lives of employes. To meet this necessity the power plant should be located as close to the pumping station as practicable, and that portion of the power system which controls the water supply should be completely independent.

At the plant with which I am connected, we not only develop all power required for plant operations, but supply the requirements of other plants and of the City of Gary, which amount to approximately 25 per cent of the total power generated. In supplying power to our city we are required to use extreme precautions to insure an uninterrupted supply, since fire-protection is entirely dependent on the operation of high-pressure, electrically driven pumps.

Although these and many other methods of producing and conserving power from by-products which are in use today are a great improvement over the methods in use even a few years past, still there is no doubt that present-day methods can be brought to a much higher degree of efficiency in practically all mills. Engineers all over the country are constantly striving to this end.

I am sure that in the interest of economy and efficiency every manufacturer who develops power from coal or plant by-products will welcome the advent of the superpower system, since it will help to absorb the surplus energy during periods of low demand at the plants. Yet this will not solve entirely all of the problems connected with saving by-products which must now be necessarily wasted during Sunday and holiday periods. It is important that every mill organization do its utmost to find a solution in their respective plants.

The Secretary: A meeting of the Board of Directors will be held immediately at the close of this session in the usual room at the east end of the corridor. Luncheon for members and their guests will be served in this room

and in the West Ballroom at one o'clock. The afternoon session will be held as formerly in the East Ballroom, just behind this screen, and you are all requested to assemble a few minutes before two, because it will be necessary on account of the long program to start the session promptly at two o'clock.

In connection with the length of our program, I wish to say that the committee was able to arrange for a number of very important papers, and they thought it best to present all these papers and to sacrifice in the matter of verbal discussion rather than to operate in the other direction. Therefore the number of those who have been given an opportunity to discuss these papers is rather limited, more limited than usual. The committee, however, desire you to understand that this arrangement was necessary on account of lack of time, and that they will be glad, if any member has conducted investigations with regard to any of these matters, to have him submit a written discussion, and all such written discussions will be very carefully considered.

The banquet this evening will be in this room. We will assemble at seven o'clock and sit down promptly at seven-thirty.

JUDGE GARY: Adjourned to two o'clock. Be prompt.

(A recess was then taken until 2 P. M.)

Members assembled in the East Ballroom at two o'clock, Mr. John A. Topping, Vice-President, in the chair.

VICE-PRESIDENT TOPPING: Gentlemen, Judge Gary has asked me to take charge of the afternoon session, which I am very glad to do, and I hope that you will all pay strict attention to the very excellent papers I see listed.

The first paper on the list is The Steel Requirements of the Automotive Industry, by Mr. Henry Chandler, metallurgist, C. H. Wills & Company, Marysville, Michigan. I have just received word from Mr. Chandler that he cannot be present. The paper will therefore not be read, but will be published with the others.

THE STEEL REQUIREMENTS OF THE AUTOMOTIVE INDUSTRY

Henry Chandler

Metallurgist, C. H. Wills & Company, Marysville, Michigan

Primarily, the physical properties of automotive steels determine which of those steels are best adapted and most essential to the automotive industry. Speaking generally, the mechanical characteristics of materials determine, first, the thing we are able to make, and second, the methods we are to employ in making it. The discovery of each new material is invariably followed quickly by the development of many new devices to adapt this new material to man's use. Conversely, the removal from the market of any of our common materials, such as copper or rubber, would result in a far-reaching industrial readjustment.

The more highly specialized an industry becomes in its development, the greater is that industry's dependence upon the properties of the metals peculiar to it. Our first thoughts in the development of a mechanical idea are governed by and limited to the materials then available. Later, competition and a fuller understanding of our actual needs result in the discovery of materials still more suitable. For instance, in the early pioneer days of the motor car industry, crankshafts were made from billets intended for rails, gears from tool steel, cylinders from iron suitable for stoves and, similarly, all other parts were made of the only materials then available.

Such practice would now be not only impractical, but actually impossible. Today we rely upon specialized automotive steels for our major parts. The automotive manufacturer is now buying physical properties. The

chemical specifications, from which steels are actually purchased, are not of importance in themselves but only for the physical characteristics which they define. It is the mechanical characteristics of the steels that are of prime importance to the manufacturer, both in the design of his product and in the mechanical methods he is to employ in manufacturing it. These are the two factors that determine his commercial success.

It will be necessary in this report to generalize. It is manifestly impossible to treat the numerous parts of a motor car individually. The steels now used by the automotive industry, their treatment and characteristics, can be found amply described in the specifications of the Society of Automotive Engineers and other organizations. Detailed application of these specifications to a given part or group of parts is impractical without a thorough knowledge of the conditions demanded and can be of only individual interest. We will, therefore, only attempt to determine which of the many steels now used by the automobile builder are characteristically "automotive steels" and the general properties such steels must possess, in terms of the tests usually applied to them.

The adoption of a steel for commercial purposes is predicted upon two general questions; first, "How will this steel adapt itself to the necessary manufacturing processes?" and second, "Will the part, when made of this steel, withstand the forces, such as wear, breakage, etc., that operate for its destruction?" The answer to these questions is obtained through a survey of the mechanical characteristics of the metal. This two-fold importance of the physical properties suggests a natural division of the various parts of motor cars.

Steels Suited to Process of Fabrication

Our first group will contain all those automotive parts which are made from steels in which the physical prop-

erties, that control the processes of fabrication, are of first importance.

This group includes most of our sheet metal parts, low stressed bolts, nuts and other screw machine products, as well as miscellaneous forgings, hardware and stampings. Such parts, due to design, when made from almost any material which will commercially meet the manufacturing requirements, are amply strong and tough to withstand all normal service conditions. Our specifications for this group are directed to simplify fabrication.

These requirements are easily and quickly ascertained. As a matter of fact, actual use becomes the best criterion and we are able to define our steels in terms of how they must behave in the shop. Our deep-drawing stock must draw deeply. Our screw machine stock must machine readily. Our forging bars must be free from defects and respond readily to forge and machine shop operations. Uniformity of quality is as important as degree of quality.

In general, requirements of this nature are not peculiar to the automotive industry. They are common to all industries where steel is similarly fabricated and such steels are "automotive steels" for the single reason that large quantities of them are consumed by the automotive industry.

In particular cases, however, the manufacture of certain individual parts of this group has been developed into separate specialized industries and we here find a corresponding development of individual steels of this class into special steels. This has been the case particularly with frames, fenders, cold-headed bolts, disc wheels, bodies, etc. Each of these presents its individual problems and each requires its individual steel specifications, specialized proportionally to the refinements in manufacture and design which have been developed by the individual manufacturer.

Chemically expressed, the needs of this group are

amply met by the standard grades of carbon steels now manufactured.

Steels Suitable for Service Conditions

The second group contains those special automotive parts which are made from steels in which the physical properties demanded by service conditions are unusual and of first importance. Steels for such parts, due to the peculiar conditions of service to which they are subjected, must have individual physical properties developed to an unusual degree. The mere ease of manufacture is of secondary importance and is considered only after the service requirements are amply met. Valves, ball bearings, magnets, armatures, hardened keys and the like are all typical of this class.

For example, in valves, strength, hardness and toughness must be maintained at high temperatures and the metal must withstand the corrosive and erosive effects of the products of combustion. To meet these particular requirements, many special steels have been developed, such as high-tungsten, silicon-chromium, cobalt-chromium and others, each with its own peculiar advantages for this service, and each with its own distinct engineering following. It was only after long, intensive development of materials that ball bearings became possible for motor car use. Also the electrical properties now attained in armature and magnet steels are evidence of the specialized nature of these parts.

Naturally, then, this group requires special analyses. The manufacture of these parts or of the steels suitable for them can be commercially undertaken only after a thorough understanding of the complex problems involved. Adequate treatment of this specialized group is manifestly not within the scope of this paper.

Steel for Major Automotive Parts

The third group, and that one with which we are chiefly concerned, contains most of our major steel parts.

The front axle and its various component units; our power train from piston pin, through connecting rods, crankshaft, transmission, universal joint, to the rear axles; springs; heavy duty gears; and, in general, all parts subjected to live loads of a high order are included in this division.

These parts are uniquely automotive parts, that is, the forces of wear, fatigue and breakage to which they are subjected; the processes by which they are fabricated; and the economic factors which limit their cost, are peculiar to and characteristic of the automotive industry alone.

The steels for these particular parts may, therefore, be truly called "automotive steels." Their development into the many standard grades of alloy steels has been coincident with and in a large measure responsible for the development of the motor car.

Parts in this group, in operation, are subjected to much punishment. Wear, shock, vibration, torsion and other complex application of forces all tend to destroy their usefulness. Our steels must resist all these and at the same time readily and economically adapt themselves to the numerous processes of forging, heat treatment and machining, incidental to the production of these parts. The quality of our part cannot be separated from the cost of our part.

Tests Used to Determine Mechanical Properties

How then are the mechanical characteristics necessary to fulfill these conditions determined?

The automotive manufacturer relies upon two types of test: first, that of actual use itself, and second, comparatively simple and rapid laboratory tests, whose indications he has learned to correlate with the results of actual use.

The test of actual use, while undoubtedly our final criterion, nevertheless has serious disadvantages. It

is generally slow and its results are difficult to express in terms usable in steel specifications. We cannot, for instance, describe our steel to the producer by stating that it must be the best and cheapest for our crankshafts, gears or other parts. We must have a means of measuring these requirements; some common method of defining the degree of hardness, strength, or other desired property. Therefore, laboratory tests, whose results may be numerically expressed, have been devised to furnish us with information as to the likely behavior of the metal in service. Such tests, in general, consist in measuring comparatively definite physical quantities by simple experiments which may be rapidly carried out and whose results may be easily checked.

It is not yet easy to say which and how many of the various physical properties, which metals possess, are of direct importance in the construction of these automotive parts. The conditions under which a motor car must operate are unusual. Long, hard, uphill or sandy pulls, shocks from rough and choppy roads, brakes suddenly applied, continued high speed, all these subject the mechanism to stresses and strains, and combinations of destructive forces, the results of which are difficult if not impossible to calculate. It is not a question of resistance to simple static stresses, but of the ability of the parts to withstand dynamic forces or the work done by these forces. The phenomena embraced in the terms fatigue, vibration and shock become important.

Dynamic tests, designed to isolate and measure the physical properties which determine the behavior of steel under these conditions, have been suggested. However, the great complexity of the various factors which determine the results of such tests and the little understood influences of slight changes in test conditions have limited their use, with but few exceptions, to qualitative rather than quantitative results.

Of the many properties easily measured, the auto-

motive manufacturer depends chiefly upon those obtained by the following tests:

First, the tensile test

Second, the Brinell and scleroscope hardness tests

Third, an impact test (in this country generally the Izod)

Fourth, thermal and metallographic investigation.

These tests, while not conclusive, nevertheless, when properly interpreted and supplemented by close observation of actual service, sufficiently define our steels for commercial purposes. Therefore, we will confine our discussion to the characteristics of these steels as disclosed by the above simple tests.

Chief reliance is placed in the tensile test. It will be readily admitted that the use of some sort of a dynamic test, which would more closely approximate the conditions of automotive service, would be more justified. Nevertheless, the permanence of the tension test and the general acceptance of its data by both steel producers and steel consumers, lead us to anticipate that its results, when supplemented with other information, will within limits tell us much of the probable dynamic character of the steel.

Briefly, the tension test is this: A bar of steel, of known dimensions, is subjected to a tensile load. This load is increased gradually, until rupture of the steel occurs. The maximum force so withstood by the bar is recorded as the ultimate tensile strength. The smallest load necessary to produce permanent set in the bar is designated as the elastic limit. Both of these are calculated on the basis of one square inch cross section. The percentage of increase in length and the change in cross section, due to the flow of the metal at the point of fracture, are also measured and calculated. The former of these is called the percentage of elongation and the latter, the percentage reduction in area.

Obviously, such a test does not duplicate the conditions to which the steel is subjected in actual motoring service. Its real value lies in our ability to correlate the data so furnished with the results of our other tests and the results of actual engineering experience. Tensile strength, elastic limit, reduction in area and elongation, these simple properties, when taken individually, convey little; but collectively, and with proper emphasis on their relation to each other, they form a sound basis for estimation of quality.

Motor car parts are with few exceptions of great enough size and mass to withstand many times the static load which they are called upon to bear. As a matter of actual practice, it is the ability to take punishment, such as shock, vibration, impact and the wear and tear of the roads, that we require of our materials; and it is the ability of a unit mass of steel to withstand work done upon it that we try to determine.

Remembering, then, that the physical properties, made evident by the tensile test, are properties of a test bar and are only indirectly properties of the steel tested, let us examine the results of this test in terms of the work actually done and the metal actually affected.

During the breaking of the bar, we are doing work; that is, we have a measured variable force starting at the elastic limit, gradually increasing up to the ultimate strength and then decreasing to the breaking load, which moves in all a distance equal to the total elongation of the bar. Since both the force applied and the distance through which it moved are known, the work done is easily calculated.

The actual amount of the material in the bar, the usefulness of which is practically destroyed by this work, is more difficult to determine. Our reduction in area, however, gives us an indication of this quantity. When we examine the test bar after the test, it will be found that the metal directly back of the fracture is still able to withstand a slight amount of work; still farther back, more

work; and so on until metal but slightly affected is reached. The reduction of area describes and is a rough measure of the degree of this condition. It is of more importance qualitatively than quantitatively.

Consider for a moment the following illustrations. Fig. 1 represents a fractured tensile test bar of a material of low reduction in area, as characterized in certain

FIG.-1

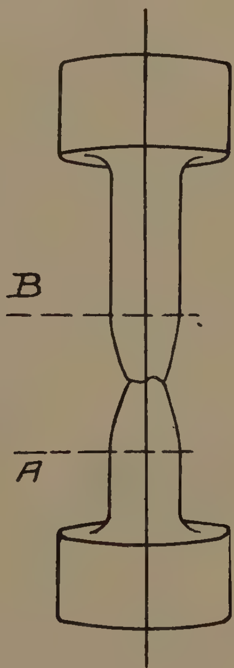

FIG.-2

bronzes. Fig. 2, a similar bar of a material such as an alloy steel, showing high reduction in area. Let us, for the sake of argument, assume that the mean breaking strength and percentage of elongation were in each case identical. Thus, with no further evidence to go by, it would be assumed that the materials were equally strong and tough and equally suitable for our motor car part.

It will be observed, however, that there is a marked difference in the appearance of the two test pieces. The steel bar shows a marked necking down at the point of fracture, due to the local flow of metal between the lines "A"—"B," while the bronze bar has stretched almost uniformly throughout its entire length. Hence, although the same amount of work was performed in rupturing both test pieces, it can be readily seen that the mass of metal affected in the bronze was considerably greater than that in the steel. Consequently, the resistance of a unit mass of the material of bar No. 2 was greater and the reduction in area is a measure of this fact. The higher the reduction in area, other conditions being equal, the greater the ability of a unit mass of the steel to withstand work done upon it.

The tensile test may therefore be considered as a dynamic test where work is done at a slow rate. Its results, as a measure of work done and metal affected, while not numerically exact, are at least proportional to them. This relationship might, roughly, be expressed as follows: Quality of metal as evidenced by the tensile test is equal to $\frac{\text{Work Done}}{\text{Metal Affected}}$

which is proportional to $\frac{\text{Mean Breaking Strength x Elongation}}{\text{K—Reduction in Area}}$

where "K" is a constant, the value of which varies with the type of fracture, and the mean breaking strength is the average force applied to the bar after the elastic limit has been passed.

It is common practice, as a check, to supplement the tensile test with an impact test in which a notched test bar is broken at a rapid rate by a falling hammer. The Izod test, in this country, enjoys the most widespread use. The work done is recorded directly in foot pounds and the mass of metal so affected, due to the mechanical effect of the notch, is in each piece fairly constant.

Our hardness test, as determined by the Brinell and scleroscope, is used as a check on our heat treatment processes and as an index to machineability and resist-

ance to wear. The results are purely empirical and of value only when coupled with the observations of experience.

Difficulties will immediately arise if we endeavor to apply too literally the results of any of these tests to conditions greatly different from our test conditions. Other considerations, based upon the metallographical makeup of the steel, may greatly change these results under the conditions of actual service. Steels, as a class, are composed of a mixture of crystalline and amorphous materials. The relative sizes, proportions, distribution and qualities of these constituents, play an all important part in the behavior of the steel, under various applications of forces. Metallographical and chemical investigation are doing much to determine this relationship between microstructure and physical properties. However, in uniform materials, uniformly heat treated, these conditions are fairly constant, and except in special cases to determine soundness, metallographical investigation is largely confined to pure research.

Effects of Heat Treatment

Steels for the parts now under discussion are invariably used in the heat treated state. The behavior of the steel under thermal treatment also bears a relation to its dynamic characteristics.

When a piece of steel is heated beyond its critical point, it undergoes a chemical and physical transformation. If thereafter it be slowly cooled, this transformation reverses itself and the material returns to its normal state. However, when the steel is quenched, the physical and chemical changes which took place during the heating have now no opportunity to reverse and the material, when cool, is consequently in a state of unstable equilibrium. This degree of instability is measured by the temperature to which we can subsequently reheat or "draw" the steel after quenching and still maintain our requisite strength. In other words, the higher the drawing tem-

perature that the steel can withstand, the greater is its molecular stability and the greater is its resistance to any subsequent molecular change, whether the latter be produced mechanically or otherwise.

Other factors being equal, the steel with the highest drawing temperature will be the most satisfactory for those automotive parts that require resistance to "fatigue."

But here again caution must be exercised lest our conclusions carry us beyond a logical point, because the metallographical size, nature and distribution of the constituents of the steel are also factors to be reckoned with.

We have indicated in the preceding paragraphs that the merit of a steel for motor car use was closely related to the results of the tension test; and that this relationship might be expressed by the proportion:

$$\frac{\text{Mean Breaking Strength x Elongation}}{\text{K—Reduction in Area}}$$

It is perfectly obvious that such a simple proportion as the above can in no way be an exact statement of the really complex relation which exists between the phenomena occurring in the tensile test and the exceedingly complex combinations of properties required for our various parts. Nevertheless, since this test so greatly influences the automotive manufacturer, in his choice of steels, we are justified in considering what further information it can supply us with.

The physical properties of our steels are direct functions of the drawing temperature. Thus the elastic limit, elongation and reduction in area may all be varied over wide limits by heat treatment.

It therefore follows that our merit number, as previously computed, will also change in value according to changes in the drawing temperature and will in a given steel reach a maximum at some definite temperature.

For example, a hardened but not drawn bar of high carbon steel may show an elastic limit of say 175,000

pounds per square inch. Nevertheless, it can be readily seen by breaking the bar with a hand hammer that this strength is of little use for the parts under discussion. Due to the slight elongation and reduction in area possessed by the bar, these factors in our equation will be small and our merit number will be very low, in spite of the relatively high elastic limit. If we now reheat or draw the bar, we find that although of less strength as measured by elastic limit, it will easily withstand our efforts with the hand hammer. A further increase in temperature still further increases the amount of energy which must be expended before breakage occurs, until a maximum point is reached where the decrease in tensile strength and elastic limit is not compensated for by the corresponding increase in elongation and reduction in area. Further elevation of the drawing temperature beyond this point results in a decrease in merit until the critical point is reached, with its accompanying fundamental changes in qualities. This drawing temperature at which maximum merit occurs is different in different types of steel and is fairly independent of the carbon content. This consideration is important in comparing the suitability of the various steels for different uses and in defining our practice in allotting a particular analysis of any given type of steel to a particular part.

Thus we find that the steels in which this temperature of maximum merit is naturally low are used exclusively in the condition resulting from low drawing temperatures. This is the case with silico-nickel steels which are widely used for hard light armor plate.

Our most widely used spring steel is of an analysis which develops the necessary spring requirements of strength, etc., at a drawing temperature but 60° removed from the temperature of maximum merit for that steel.

It is common practice in the manufacture of large carbon steel forgings to meet the elastic limit requirements in so far as possible by carbon additions and thus maintain a high drawing temperature. Since there is,

then, a definite drawing temperature, at which the dynamic properties required in automotive steels are developed to their maximum, for each particular steel analysis, there is, consequently, a corresponding definite elastic limit at which that steel may best be used.

Most of our major automotive parts require, owing to the limitations imposed by design, minimum strengths of a relatively high order. Also the successful operation of these parts, under the difficult service conditions, presupposes the development of the merit index to a high degree.

Carbon steels may develop under suitable heat treatment elastic limits which are sufficient for most of these parts, but their use is promptly excluded where the requirements exceed 80,000 pounds per square inch, and even for requirements under this figure the merit index is of a lower order than is desired.

Accordingly, our automotive alloy steels have been developed, which not only will show higher elastic limits than those obtained in carbon steels, but also for any given elastic limit, demanded by design, will exhibit resistance to fatigue, vibration, shock and wear, far greater than that of any carbon steel.

This development has been coincident with and in a large measure responsible for the development of the automotive industry.

The commercial factors, as defined by the adaptability of these materials to the various mill processes of manufacture and the subsequent operations of fabrication such as machineability and general adaptability to shop conditions, have in a like manner been improved until it may now be fairly said that through the use of alloy steels, the automotive manufacturer can build a better product at a cheaper price.

Vice-President Topping: The next paper on the program is Heating Furnaces for Blooms, Slabs and Billets, by W. P. Chandler, Jr., fuel and experimental engineer, Carnegie Steel Company, Duquesne, Pa.

HEATING FURNACES FOR BLOOMS, SLABS AND BILLETS

W. P. Chandler, Jr.

Fuel and Experimental Engineer, Carnegie Steel Company, Duquesne, Pa.

I have been asked to prepare a paper on "Heating Furnaces for Blooms, Slabs and Billets," with special attention to fuel economy. If taken broadly, this subject would include all types of furnaces with the different methods for firing the various fuels in use. I shall, however, cover briefly the various methods of firing metallurgical heating furnaces, and describe particularly two certain types of furnaces with which I am particularly acquainted. These furnaces use by-product coke oven gas as fuel, but conclusions can be drawn from the results of tests, that may be applicable to future development of furnaces using any type of fuel in order to obtain more efficient and better heating.

Selection of Fuels

The choice of fuels for use in heating furnaces is governed by availability and cost. When natural gas was plentiful and cheap practically no other fuel was used, but with the growing scarcity of this fuel, operators have been forced by considerations of cost and even by law to substitute other fuels.

The gaseous fuels such as natural or by-product gas are ideal fuels for use in heating furnaces. They require the least amount of equipment; a gas main, regulator and burners with necessary valves make a complete installation. The varying demand of the furnace can readily be met with an increase or decrease in the supply of fuel, while the temperature of the furnace can be

held at any point within the range required for heating steel. The most important factor governing the successful use of a gaseous fuel is the maintenance of a constant pressure on the burner valves. This can be accomplished by the installation of an automatic pressure regulator.

Liquid fuels such as by-product tar and fuel oil require additional equipment. A storage tank equipped with some means of heating the fuel, such as pipe coils filled with steam, a pump, pressure regulator and atomizing burners with the necessary piping and valves make up the usual installation. The atomizing burners may be of the pressure type or may require steam or compressed air, in which case a source of supply for the atomizing agent must be provided. As in the case of gaseous fuels, constant pressure for both fuel and atomizing agent are requisite for good operation of the furnace. The main reasons these fuels have not found broader use lies in the scarcity of by-product tar and the cost of fuel oil at the main steel mill centers.

Solid fuel in the form of coal has been used in many reverberatory heating furnaces. Originally, the firing was done by hand and the ashes removed by manual labor. The high labor cost in this country has forced the development of labor saving devices. The mechanical stoker has found ready application and a large number of furnaces are operated in this manner at present. The installation, aside from the stoker proper, requires the addition of coal and ash handling machinery, bins and in the case of forced draft stokers, the necessary fans and air ducts. It also precludes to a great extent the savings that can be obtained from recuperation of the air for combustion.

Another development in the application of coal as fuel for heating furnaces has been through the use of gas producers. By this method the preparation of the fuel is removed from the furnace and the heater has to deal with only a gaseous fuel. Only about 80 per cent of the heating value of the coal is realized in the producer

gas, however, and with the rapidly rising cost of coal in this country it will become more and more difficult to justify this loss. There is a large increase in the initial cost of the furnace installation to provide the producers, building, coal and ash handling machinery, gas flues and steam lines. A general estimate of the cost can hardly be made, since much depends on the individual installation. The size of the producer plant, location with reference to furnaces served, number of furnaces to be operated from one producer plant and such items require that a separate study be made for each case. The cost of operating the producer plant, that is gasifying the coal, must be added to the fuel cost in any comparison of prices of various fuels.

In recent years powdered coal fired heating furnaces have found favor in many plants, particularly in France. A number of problems in its use will have to be overcome successfully before its adoption will become general. Removal of the ash from the products of combustion or provision for its free passage through the furnace must be provided in order to insure uniform heating of the steel. The intense flame with its consequent cutting action on the steel must be cared for, and the gain in efficiency due to preheating the air for combustion will increase this difficulty by causing a still more intense flame. A number of methods and systems for pulverizing, conveying and firing powdered coal are on the market, and if the various difficulties can be successfully overcome, material savings in fuel may be obtained.

The application of electrical heating in metallurgical work is comparatively new. Furnaces using electrical heat for heat treatment of steel, either as castings or forgings, are successful and on account of the accuracy with which the desired temperature may be maintained and the freedom from oxidation, it is found that it pays to use the more expensive fuel or source of heat, electricity. It is doubtful if electricity will be used to heat steel in the form of blooms, slabs and billets made of

ordinary steel, except in special localities where electricity is cheap and fuel is scarce and expensive. However, where steel is placed in a furnace hot and merely receives a soaking heat, as in the case of ingots in soaking pits, the amount of electric current required per ton of steel is small and it is probable that the saving due to freedom from oxidation or scale and from burnt steel will more than compensate for the cost of the electric current. Such electrically heated soaking pits have been designed, although they are not in operation at the present time.

The following table has been prepared to show the allowable price that can be paid for various fuels to be equivalent in heating value to natural gas at $0.30 per thousand cubic feet. The cost of preparing and firing the fuels has been added in arriving at the allowable price, but no allowance has been made for the efficiency obtained in the furnace itself. Also no charge for depreciation or interest on the initial investment has been made, since so much depends on the individual installation.

Fuel	Natural Gas	By-Product Gas	By-Product Tar	Fuel Oil	Coal as Producer Gas
Unit	1,000 Cu. Ft.	1,000 Cu. Ft.	1 Gal.	1 Gal.	1 Gross Ton
B. t. u. per unit *delivered* at heating furnace	950,000	496,000	156,000	137,600	24,192,000
Equivalent of 1,000 cu. ft. of natural gas	1,000	1,915	6.09	6.90	.03926
Cost of preparing per unit	00	00	$.00023	$.00023	$1.60
Cost of firing per unit	00	00	.005	.004	....
Total cost of equivalent of 1,000 cu. ft. of natural gas	$.30	.30	.30	.30	.30
Cost above fuel of equivalent of 1,000 cu. ft. of natural gas	00	00	.0304	.0276	.0628
Allowable cost equivalent of 1,000 cu. ft. of natural gas	.30	.30	.2696	.2724	.2372
Allowable cost per unit to be equivalent to total cost of 1,000 cu. ft. of natural gas	.30	.157	.044	.040	6.04

Types of Furnaces

There are two main types of furnaces in use for heating blooms, slabs and billets, the continuous and the non-continuous. The latter is similar in construction to

the Siemens open-hearth furnace, the direction of the gas flame across the hearth is periodically reversed and the furnace is usually equipped with regenerative checker chambers for preheating the air used for combustion. The blooms or slabs which this type of furnace usually heats are charged on the hearth of the furnace and remain in the one place till hot enough to roll. The continuous furnace is not reversed, the flame always traveling in the one direction, while the steel usually in the form of billets passes through the furnace in the opposite direction. The cold billets enter the furnace at the coolest point and are pushed forward to the point of maximum temperature where they are discharged to the rolls. In the continuous furnace the billets lie tight together on the skids, forming a large steel plate on the floor of the furnace. Only the top of the billet is exposed so that all the heat required to bring the steel to rolling temperature must be absorbed by this surface. In the non-continuous furnace there is an open space between the blooms, so that three sides are available for directly absorbing the heat from the products of combustion or roof, while the fourth side is resting on the heated hearth of the furnace and absorbs from it a large amount of heat.

The time required for heating billets, slabs or blooms depends on the temperature of the heating medium, the surface of the steel exposed and the thickness of the steel. The temperature of the continuous furnace is at a maximum only at the discharge end and gradually decreases to the rear, while only one side of the billet is available for absorbing heat. In the non-continuous furnace the temperature is at the maximum throughout and three sides of the billet are available for absorbing heat. It is evident, therefore, that the same sized billet must remain longer in the continuous than in the non-continuous furnace. The dimensions of the non-continuous furnace do not affect directly the time of heating, but in the continuous furnace, with the rolling mill handling a given number of bars per hour, the length of the

furnace fixes the time of heating. With everything else the same, the time of heating in a continuous furnace varies as the square of the thickness of the billet, so that a five-inch square billet requires four times as long as a two and one-half inch square billet. This means that for the larger sizes of billets long furnaces are required to give the capacity required by the rolling mill. For blooms and slabs the general practice so far has been to use non-continuous furnaces, but for 5 by 5 inch billets and smaller the continuous furnace proves very satisfactory.

Certain of the alloy and spring steels, if heated too rapidly, tend to crack, so that care must be used in bringing such billets up to rolling temperature. The continuous furnace fits this class of steel admirably since the billet enters a relatively cool part of the furnace and is gradually heated to the temperature required for rolling.

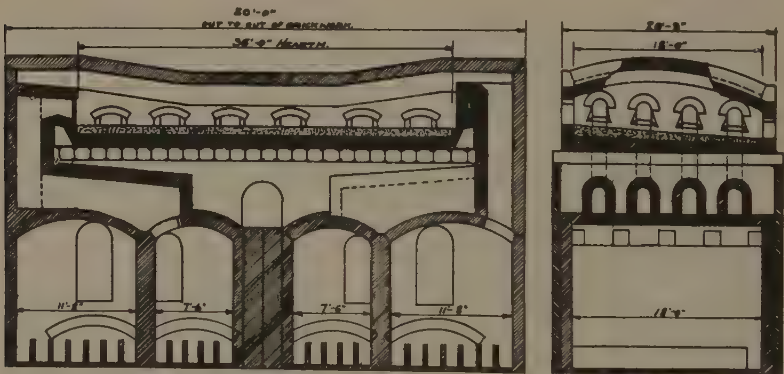

Fig. 1—Non-Continuous Regenerative Heating Furnace.

Non-Continuous Regenerative Furnace

A sketch of a non-continuous regenerative furnace is shown in Fig. 1. The hearth which is 18 feet wide by 35 feet long has a silica bottom, made by fusing sand in thin layers until the proper thickness is reached.

A slight slope toward the rear of the furnace allows the slag which forms to drain through spouts into slag

pots. The steel is charged and drawn through doors in the front by a charging machine. Four ports are provided at each end of the furnace, through which the gas with part of the air for combustion is admitted. The remaining air for combustion enters through a wide port opening between the roof and the top of the gas ports. Two regenerative checker chambers are provided at each end of the furnace, as producer gas was the fuel initially used and this gas was preheated as well as the air for combustion. The checker chambers are connected to the stack by flues containing valves and dampers, so arranged that the direction of the flow of the hot products of combustion across the hearth may be periodically reversed. In this manner the gas is first burned through one end of the furnace, while the waste gases leave at the opposite end, heating the checkers in their passage to the stack. The flow is then reversed, the gas is burned through the other end and the air for combustion is preheated in the checker chambers which have just received their heat from the waste gases.

Two of these furnaces serve one rolling mill. With one furnace containing steel heated and ready to roll, the first door is opened and the part of the hearth served by this door cleared of steel. Then the second door is started in the same manner, and while drawing the second door, the first is recharged. This is continued till all the hot steel has been drawn and the furnace refilled with cold blooms. The charging machine then moves to the second furnace and repeats the operation. By alternating the furnaces little time is lost waiting on hot steel. Blooms varying from 5 by 5 inches to 9½ by 11 inches are heated in this furnace.

Efficiency Tests of Non-Continuous Regenerative Furnaces

Method of Testing: Efficiency tests conducted on the furnace just described were made in the following manner: the amount of by-product gas used as fuel

was measured by a Wylie proportional meter, which was calibrated with a pitot tube for various rates of flow. The pressure of the gas was measured with a mercury U gage, the temperature with a mercurial thermometer, and samples were taken for chemical analysis from which the heating value was calculated. A record was kept of the number and size of blooms heated and the temperature of the steel leaving the furnace was measured by a Leeds & Northrup optical pyrometer. The steel entering the furnace was at atmospheric temperature. Analysis of the waste gases in the flues leading from the checker chambers to the stack were made with an Orsat apparatus. Four thermo-couples were installed, two at either end of the furnace, with one in each of the flues leading from the regenerative chambers to the stack. In this manner the temperature of the waste gases leaving each regenerative chamber was determined and the average of all readings used for calculating the stack loss. The temperature of the preheated air entering and of the waste gases leaving the furnace was obtained with an optical pyrometer sighted on the brick walls of the flues leading from the regenerative chambers to the ports, determinations being made on the air from each chamber. Readings were also taken of the furnace temperature with an optical pyrometer, and atmospheric temperature near the furnace with a mercurial thermometer. The barometric pressure was read during each test and the specific gravity of the gas checked periodically.

Readings of all instruments were taken every ten minutes during the test and samples of waste gas were analyzed every ten minutes.

The regular operation of the furnace consisted of a drawing and charging period followed by a heating period, which required that the starting and stopping point of the test be at the same point in the cycle in order that the gas supplied and the steel heated would bear the correct relation to each other.

Calculation of results: The following methods were employed in calculating the results shown in the following pages:

The heat absorbed by the steel was found from the weight of steel heated, the temperatures of the steel entering and leaving the furnace and the specific heat of steel which for these tests was taken as 0.166. The weight of steel was obtained from the number and weight of blooms entering the furnace. The heat supplied to the furnace was determined from the heat value of the fuel gas, as calculated from the chemical analysis and the number of cubic feet of gas burned reduced to standard condition of 62° F. and 30 inches of mercury pressure.

The losses were calculated according to the usual engineering practice, the loss to radiation being taken as the difference between the heat supplied in the gas and the sum of heat absorbed by the steel and all losses except radiation.

The efficiency of the furnace as shown is the ratio of the heat absorbed by the steel to the heat delivered in the gas. The efficiency of the regenerator was calculated by assuming that all the heat in the gases entering the regenerator was available for absorption by the air. The difference between the heat content of the gases entering and leaving the regenerator was assumed as the heat absorbed by the air. The efficiency shown is the ratio of the heat absorbed by the air to the sensible heat of gases entering the regenerator.

From the analysis of the waste gases a study was made of the infiltration of air at various points. The amount of excess air in the waste gases leaving the regenerator was first calculated. The air entering the furnace through the ports was calculated by a heat balance of the regenerator assuming no radiation. This assumption is partially true because the regenerators are entirely under ground and are therefore very thoroughly insulated. The difference between the amount

of air entering the ports and the amount of air used for combustion with the excess as shown in the regenerator gases is the amount of air that infiltrated through the doors and openings in the furnace.

Discussion of Results: From the tabulated results it will be seen that the efficiencies varied from 36 to 41 per cent. It is interesting to note that with the highest efficiency the following conditions prevailed: the lowest rate of heating steel, the lowest gas consumption, the lowest radiation and the lowest stack loss, while the reverse conditions prevailed on the test having the lowest efficiency. It will be seen that the greater rate of heating is accompanied with greater furnace temperature and the corresponding greater heat losses.

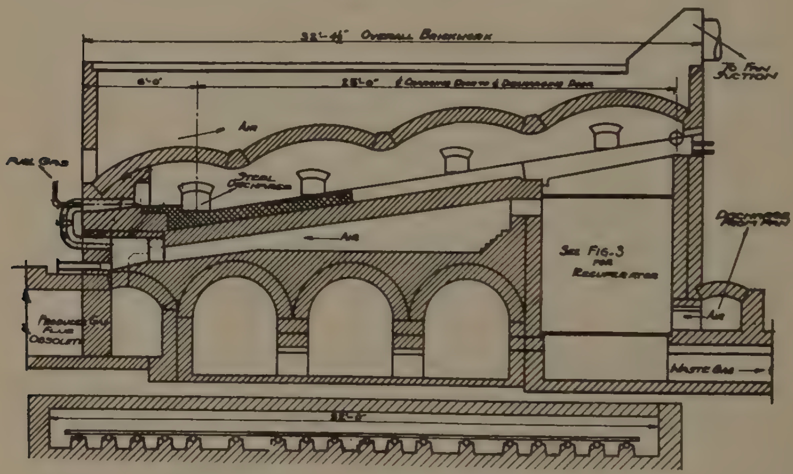

Fig. 2—Continuous Recuperative Heating Furnace.

Continuous Recuperative Furnace

A sketch of a continuous billet heating furnace equipped with a recuperator for preheating the air for combustion is shown in Fig. 2. The billets enter through a side door in the upper end of the furnace, passing into the furnace on rollers, are pushed forward on the skids of the furnace by a set of arms which operate through the rear end wall and are discharged through a small

door in the side wall at the other end of the furnace by a pusher bar driven by pinch rolls. The discharge door is in line with the first pass of the roughing rolls, so that the billet enters the rolls before being completely discharged from the furnace. This design is possible where only one furnace supplies a mill. If two or more furnaces are used the billets usually fall from the hearth through the end of the furnace, upon the rollers of the transfer table. This design necessitates having an opening in the end of the furnace extending the full width. The opening is partially closed by swinging doors, bars or pipes, but allows a large amount of cold air to pass into the combustion chamber at the point where the billets are being heated to their highest temperature.

The roof consists of four arches thrown in the direction of travel of the steel. The skewbacks for these arches are supported by a water-cooled system of pipes hung by straps from steel beams which rest on the side walls of the furnace. The side walls extend three feet above the arch. Steel trays filled with sand are placed over the beams forming an air space over the roof.

Water-cooled skids are used to bridge the opening into the recuperator chamber, but no water-cooling occurs beyond the point where the fire brick floor of the furnace commences.

Cast iron skids support the billets to within 3 feet of the discharge door where a magnesite brick bottom, built flush with the tops of the skids covers the floor of the hearth. The cast iron skids without water-cooling give excellent service.

Fifteen burners are provided across the end of the furnace. The burner consists of a cast iron return bend having a small gas pipe concentrically located in the upper leg, while the air for combustion is supplied through the lower leg which is provided with a butterfly regulating valve. Mixing of air and gas takes place beyond the nose of the gas pipe, the flame entering the combustion chamber through the ports of the furnace.

The recuperator for preheating the air used for combustion is shown in Fig. 3. It consists of vertical cast iron pipes supported by plates with additional baffling plates. The products of combustion pass downward through the pipes to a flue leading to the stack. The air used for combustion is partially heated by being drawn through the space between the roof of the furnace and the sand trays supported on the cross beams by a fan, which discharges through a flue into the recuperator chamber. The air passes upward on the outside of the cast iron pipes receiving heat through the walls of the pipes. Leaving the recuperator, the air passes under the

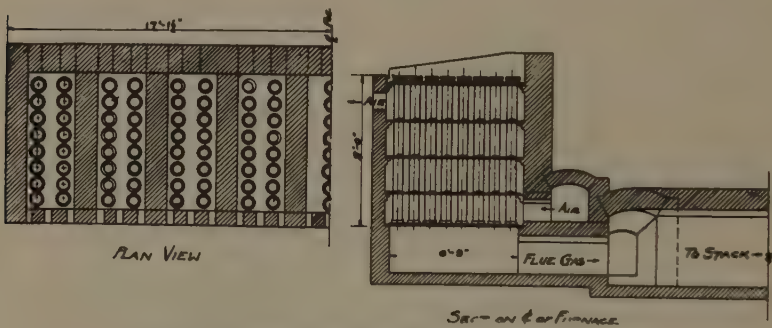

Fig. 3—Recuperator for Continuous Heating Furnace.

floor of the furnace through ducts to the opposite end, where it enters the bottom leg of the cast iron burners. The furnace is used for heating from 1½ to 2½-inch square billets.

A second continuous billet heating furnace is shown in Fig. 4. This furnace has a flat roof which eliminates the water-cooling used on the skewbacks for the arched roof. It is also equipped with a brick recuperator. The downward passageways are square brick flues, while the air for combustion is baffled, in the manner shown, to make seven passes across the heated brick walls.

The brick recuperator has received a great deal of attention abroad and a number of special form tiles have been developed with which the recuperator is constructed.

In one type, the recuperator chamber is located below the furnace. The air for combustion passes upward, by natural draft, through vertical rectangular flues, while the waste gases entering at the top travel through horizontal flues and make two passes across the outside of the air-carrying tile. Great care has been used to prevent leakage from the air passageways into the waste gas flues and the tile has been designed as thin as is consistent with the necessary strength.

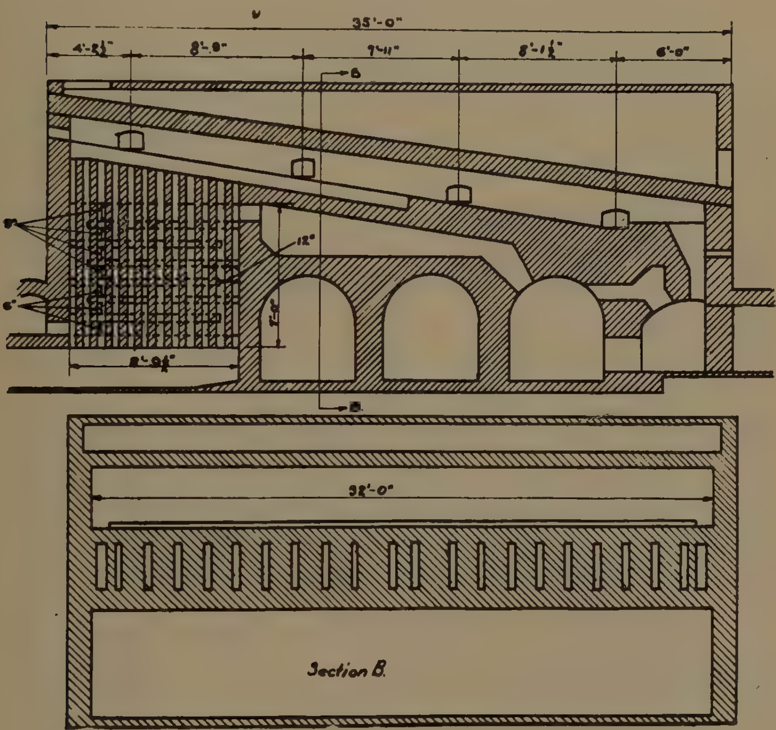

Fig. 4—Continuous Heating Furnace with Brick Recuperator.

Efficiency Tests of Continuous Recuperative Furnaces

Method of Testing and Calculating:—Tests were conducted on the two continuous recuperative furnaces just described in a manner similar to those conducted

on the non-continuous regenerative furnaces with only the necessary changes due to difference in construction. The amount of cooling-water used was measured and the inlet and outlet temperatures noted. The calculations followed along the same lines as those described for the regenerative furnace.

General Discussion of Results: The continuous recuperative furnaces are more efficient than the regenerative furnaces as shown below:—

EFFICIENCY OBTAINED

Furnace No.	Run No. 1	Run No. 2	Run No. 3	Type of Furnace
2 Mill............	62	63	58	Continuous Recuperative
5 Mill............	38	41	37	Non-Continuous Regenerative
6 Mill............	47	57	53	Continuous Recuperative

This higher efficiency is due to the method of operation of the continuous furnace; namely, the cold steel enters the furnace at one end and progresses slowly toward the other end, at which time it has become hot enough to roll.

The gases traveling in the opposite direction—from the hot to the cold end—are cooled by the steel and therefore leave the furnace chamber at a much lower temperature than the gases of the regenerative furnace. In the latter furnace all parts of the hearth are maintained at the same temperature.

TEMPERATURES OF GASES LEAVING FURNACE CHAMBER

Non-Continuous Regenerative...........................	2001° F.
Continuous Recuperative...............................	1192° F.

The principal heat losses of heating furnaces are the stack losses and radiation. The following table taken from the heat balances secured during the tests shows the relative proportions of these losses and of the heat absorbed by the steel. For the amounts of heat in B. T. U. refer to Table A, giving data and results of tests:—

Outlet temperature, degree...

FUEL GAS (By Product):

Analysis by volume—

CO_2, per cent...

C_2H_4, per cent...

CO, per cent...

CH_4, per cent...

H_2, per cent...

N_2, per cent...

Heating value per cubic foot, B. T...

Pressure of gas at meter, inches Hg...

Temperature of gas at meter, degre...

Quantity of gas by meter, cubic fe...

Calibration factor of meter...

Total gas burned std. conds., cubic...

Gas burned per ton steel, cubic fee...

Gas burned per minute std. conds...

AIR:

Barometric pressure, inches Hg...

Temperature near furnace, degree...

Temperature after roof recuperat...

Pressure at fan discharge, inches...

Pressure at entrance to recuperat...

Pressure at burner, inches water...

Loss in air pressure through recu...

Temperature at burner, degrees F...

North end, inside regenerator, de...

North end, outside regenerator, d...

South end, inside regenerator, de...

South end, outside regenerator, d...

Cubic feet excess air in recuperat...

Cubic feet excess air in stack gas...

Cubic feet air for theoretical com...

Cubic feet air through recuperat...

Cubic feet air infiltrated through...
fuel gas...

Cubic feet air used for combusti...

Cubic feet air used for combusti...
fuel gas...

FURNACE CONDITIONS:

Flame temperature, degrees F...

Analysis of gas entering recuper...

CO_2, per cent...

O_2, per cent...

CO, per cent...

N_2, per cent...

Cubic feet such gas, per cubic f...

Temperature of gas entering reg...

Per cent of total heat returned...

Average temperature gas leavin...

North end, inside regenerator...

North end, outside regenerat...

South end, inside regenerator...

South end, outside regenerat...

Stack analysis—

CO_2, per cent...

O_2, per cent...

CO, per cent...

N_2, per cent...

Cubic feet, per cubic foot fuel...

Temperature of stack, degrees...

EFFICIENCIES (Per Cent):

Furnace...

Recuperative, based on availa...

HEAT BALANCE:*

Heat delivered, per hour

Heat absorbed by steel, per h...

Loss of heat in cooling water...

Loss to moisture burning H_2...

Loss to dry stack gases

Loss to radiation

HEAT BALANCE IN PER CENT.

Furnace No.	Type	Test No.	Per cent. Heat in Fuel Gas	Per cent. Heat to Steel	Per cent. Heat to Cooling Water	Per cent. Heat in Stack	Per cent. Heat Radiated
2	Continuous recuperative.....	1	100	62	1	20	17
2	Continuous recuperative.....	2	100	63	2	21	14
2	Continuous recuperative.....	3	100	58	1	20	21
5	Non-Continuous regenerative	1	100	38	....	27	35
5	Non-Continuous regenerative	2	100	41	....	27	32
5	Non-Continuous regenerative	3	100	37	....	31	32
6	Continuous recuperative.....	1	100	47	2	30	21
6	Continuous recuperative.....	2	100	57	2	28	13
6	Continuous recuperative.....	3	100	53	2	29	16

This table clearly shows the reason why the use of regenerative furnaces should be limited to only those places where it is impossible to apply the continuous recuperative furnace, for less than half of the heat in the gas enters the steel in the non-continuous regenerative type. The regenerative furnace does not lend itself to insulation to prevent radiation, because the temperature over the entire chamber is the same and usually so intense that if insulation were applied the limit of the refractories would be reached and the furnace destroyed. The continuous recuperative furnace, on the other hand, does lend itself to insulation to prevent radiation, because this furnace is comparatively cool and most of the radiating areas can be insulated.

The two continuous furnaces tested had different recuperators as before mentioned. The following table gives the losses in air pressure through the two types:

DROP IN AIR PRESSURE THROUGH RECUPERATORS, IN INCHES OF WATER

Furnace No.	Type of Recuperator	Run No. 1	Run No. 2	Run No. 3
2	Brick.............	2.11	2.40	1.55
6	Cast Iron.........	1.18	1.38	1.41

The greater drop in air pressure through the brick recuperator is due mainly to the sharp turns around the ends of the baffles placed in the recuperator. The cast iron recuperator also has a distinct advantage over

the brick recuperator in that its passages can be made of such shape and with surfaces smooth enough that the drop in air pressure through it will be less than can be secured in brick recuperators, where the passages in most cases must be made of rectangular cross section and have rough surfaces. Cast iron is also much better for conducting heat than fire brick.

In both series of tests on continuous recuperative furnaces the efficiencies were highest when the largest size billets were handled. The following table gives the size of billets, radiation loss and efficiency for the series of tests on the two recuperative furnaces:—

Furnace No.	Test No.	Billet Size in Inches	Per cent. Radiation Loss	Per cent. Efficiency
2	1	3¼ x 3¼	16.48	62.18
2	2	3¼ x 3¼ and 2½ x 2½	14.54	63.07
2	3	2½ x 2½	20.84	58.29
6	1	2 x 2	20.74	47.30
6	2	2½ x 2½	13.18	57.41
6	3	2½ x 2½	16.06	52.52

It will be noted that the series on the smallest size billets had the largest radiation loss. This may be due to improper operation or design. When operating with the smaller size, the billets heat more quickly and are at rolling temperature before arriving at the discharging end. This causes a higher average temperature of steel, roof and side walls inside of the furnace, causing the greater radiation loss.

Conclusions and Recommendations: The data here shown was obtained, as mentioned before, on furnaces using by-product coke oven gas as fuel, but the following recommendations for future development will apply in the main to furnaces using any kind of fuel.

From the results shown in these tests, the development of heating furnaces should be along the lines of continuous recuperative furnaces unless some special reason makes it necessary to use another type. As has

been shown the recommended type is superior to other types, as it is now built, and can be made even more efficient by development.

The furnace consists of a number of individual units, that is, roof, hearth, skids, burners, pusher, roof recuperator, main recuperator, discharge and charging mechanisms, meters and regulators, insulation and water-cooled devices. These will be taken up independently and recommendations tabulated.

A. Roof. The roof should be placed at such a height above the steel that the gases may wipe both surfaces and yet not cause too much resistance to their flow. A flat roof eliminates the necessity of water-cooling the arch supports. Some method of corrugation may be advisable to increase the surface for absorbing heat from the products of combustion. This would make available more heat for radiation from roof to steel and increase the rate of heat transfer.

B. Hearth. The hearth of the continuous furnace should be sloped from the charging end to the discharging end, care being exercised that the slope is not too great. This applies especially to long furnaces which are to handle large billets. The use of a basic lining for reversing furnaces would give a supply of basic cinder. This can be used in open-hearth furnaces to replace lump ore, and therefore deserves careful consideration.

C. Skids. Solid cast iron skids should be installed on the floor of the furnace, to eliminate the heat lost in cooling-water and to simplify construction.

D. Burners. A series of burners should be installed across the width of the furnace in order to secure a uniform temperature. The burners should be equipped with valves for the independent control of both fuel gas and air for combustion.

E. Regulators and Meters. Each furnace should be equipped with some means whereby the gas and air pressures on the burners may be automatically maintained constant. Each furnace should be equipped with

an integrating and recording device which will accurately measure the amount of gas delivered to the furnace.

F. Pusher. A pusher for advancing the steel along the skids of the furnace should be provided which will give a uniform motion that can be regulated very closely, both in regard to distance and speed. This mechanism may be actuated by either a hydraulic cylinder or a reversing motor.

G. Roof Recuperator. The use of a roof recuperator should be limited to that section of the roof in which the refractory property of the brick will not permit it to be insulated.

H. Discharging and Charging Mechanism. The side discharge which was explained in the description of the continuous furnace is superior to the dropping end discharge from a fuel standpoint. It eliminates the loss of heat due to the exposure of a poorly insulated surface to radiation from the hottest zone of the furnace, as it is impossible to properly insulate the swinging door on account of its construction and the abuse it receives. The side discharge admits less cold air to the furnace chamber and a side charging mechanism prevents to a large extent the leakage of air into the furnace.

I. Main Recuperator. The use of metal in recuperator construction has certain advantages over brick. It has a greater heat transfer rate and is not as susceptible to cracking with the consequent air leakage. The possibility of a design with the use of pipes or tubes similar to water tube boilers looks very attractive.

The recuperator should be constructed so that it offers the least resistance to the flow of air and gas consistent with good heat transfer. The gas and air passages should be designed so as to give as nearly uniform velocities at all points as is possible. That is, the variations in the volume of gas and air due to their varying temperature should be considered. It may be advisable to have the air flow through three banks of tubes in series with the waste gases passing over the outside.

The tubes should be staggered to give the maximum heat interchange.

The recuperator should be located in such a position that it would be easily accessible for inspection and repair. Placing the recuperator above the furnace instead of under ground should be very carefully considered. A better distribution of the waste gases both through the furnace and in the recuperator would be possible than is the case where the entrance to the recuperator is directly below the steel to be heated, since the gases must pass over the ends of the billets. Additional insulation would be required but no drainage water could collect in the bottom of the chamber or flues.

J. Insulation. Insulation should be used to prevent radiation as far as is possible without reaching the refractory limit of the fire brick and yet remain under the point where first cost would overbalance economy.

K. Water-Cooled Devices. Water-cooled parts should be avoided wherever possible, because they are hard to keep in repair, dissipate an appreciable amount of the total heat of the gas, and their elimination reduces the cost of supplying the cooling water.

L. Waste Heat Boilers. Several installations of waste heat boilers have been made in connection with heating furnaces. However, the development of the recuperator holds such possibilities that furnace efficiencies comparable to good boiler practice should be obtained. Future development, however, may show that in some cases of non-continuous regenerative furnaces the waste heat boiler may have a field.

It will be observed that heating furnaces have been brought to a fair degree of development. The efficiencies obtained are not comparable to those of the best heat interchanging appliances, such as boilers and blast furnace hot blast stoves. With the rapidly increasing cost of fuel in this country, it becomes very important that all heat using appliances be made as efficient as possible, and concerted effort along the lines of recupera-

tive furnaces should be productive of material savings in fuel. Co-operation among the members of the Institute in this development will result in enormous savings to the industry.

Vice-President Topping: In discussion of Mr. Chandler's paper, I will call on Professor Willibald Trinks, Carnegie Institute of Technology, Pittsburgh, Pa.

Discussion by W. Trinks

Professor of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

I am sure that the Institute is very much indebted to Mr. Chandler for the paper which he has prepared, and likewise to the Carnegie Steel Company for allowing the information to be published. Any contribution which I may be able to make by a discussion is not given in any spirit of criticism, but rather as an analysis of the paper with a view to making it even more valuable.

Mr. Chandler is doubtless correct in making the statement that natural gas and by-product gas are ideal fuels for heating furnaces. Looking into the future to a time when coal will be scarcer than now, we cannot help but feel that we will probably have to use a mixture of by-product gas with blast furnace gas. In many respects, that mixture will be superior to pure by-product gas, because it will allow the use of highly preheated air without the overheating of the combustion chamber.

In describing the practice of the Carnegie Steel Company with regard to regenerative mill-type furnaces, Mr. Chandler states that only two furnaces are used per mill and that the furnaces are always kept at maximum temperature. The Carnegie Steel Company may, as the slang expression says, get away with it, because the mill in question rolls only very soft carbon steel, but as a general practice that method is not to be recommended. There should be three furnaces.

With that arrangement, while one is being worked out or emptied, another is being heated, and the third furnace is being charged and the heat started. If that is done, the billets or blooms, when first charged, lie in a comparatively cool furnace, because they pull the furnace temperature down. Mr. Chandler says, also, that billets are heated faster in regenerative furnaces than in continuous furnaces. I have seen blooms heated in continuous split-flame furnaces just as fast as they are heated on the hearth of a regenerative furnace. This statement does not imply the thought that fast heating is a desideratum. Quite the contrary, slow heating is better, particularly for high carbon steel.

The statement, "In the continuous furnace, with the rolling mill handling a given number of bars per hour, the length of the furnace fixes the time of heating," is apt to be misunderstood. I would put it the other way around and say: "The length of the furnace and the size of the billet fixes the number bars which the mill can handle per hour." At least I know quite a number of mills in which the heating furnace limits the mill capacity. If continuous furnaces with end discharges are used, then we can say: "The length of each furnace, the size of the billets, and the number of the bars to be heated per hour fixes the number of furnaces which are required to do the job."

Although the paper does not exactly say so, it intimates that the batch-type furnace is to be preferred for billets from 5 inches by 5 inches up, and that the continuous furnace is to be preferred for smaller sizes of billets. To my mind, the size of the billet or bloom is not the deciding factor. I know a mill in Pittsburgh which heats 9-inch by 9-inch blooms in continuous furnaces. A mill near Philadelphia pushes 17-inch by 17-inch ingots over skids. A mill in Central Pennsylvania pushes 22-inch ingots through continuous furnaces, and a mill near Pittsburgh uses a continuous furnace for 24-inch ingots. To carry this criterion to the other

extreme, skelp is never heated in a continuous furnace. This seems to indicate that we should heat in continuous furnaces everything that is of suitable shape and sufficiently regular in size and quantity for that purpose. Every steel plant has some step-child of a mill which handles small and irregular orders. The billets vary in size, in shape, in length, in composition. Frequent shut-downs for roll changing occur. Evidently, that mill is no place for a continuous furnace. The outer skids would be bare half of the time; the rate of heating would not be right for both large and small sections; the recuperator would be burned out while the steel was being kept hot during roll changes, and so forth.

It may also be mentioned that one of the principal reasons for the introduction of the continuous furnace was not fuel saving, but labor saving. That feature was very strongly stressed in the patent law suits which followed the early days of the use of the continuous furnace.

With regard to the test methods which were used by Mr. Chandler, it must be admitted frankly that they are absolutely standard in steel mill practice. But, being a college professor, I may be pardoned for finding fault with some of the items. One is the calibration of a gas meter by a pitot tube. In general, I would say that anybody who uses a pitot tube for calibrating another instrument is an optimist. It may be that in the three furnace tests described in this paper, there was in each case a long run of straight pipe absolutely free from eddies, or that a careful search was made of the velocities over the whole cross-section of the pipe, in which case the results will be reliable; but, for high class test work I prefer the following method; break the pipe between the meter and the furnace, and put on the pipe end a well-rounded standard orifice, as obtainable for instance from the Bacharach Instrument Company; measure the total static plus the dynamic head by an impact tube for several rates of flow and more partic-

ularly for the rate of flow which the gas meter indicates in the regular run of the furnace. I fully realize that the test engineer needs a special dispensation from the mill superintendent before he is allowed to break the gas main, whereas he can go ahead at any time and drill a hole in the line without permission and without having to invoke the good graces of the pipe fitter, but that realization does not alter the fact that the method of calibration by a standard orifice is more reliable.

A second method used by Mr. Chandler is quite standard in steel mill practice, and yet its accuracy is very doubtful. I refer particularly to the measuring of the temperature of flue gases or of preheated air in regenerative furnaces by either a thermo-couple in a protecting tube or by measurement of the temperature of the surrounding brick wall by an optical pyrometer. That neither of the two methods can indicate the true temperature becomes clear from the statement that neither a thermometer hanging in the sunlight nor a wall in the sunlight assumes the temperature of the surrounding air. That a thermo-couple in a protecting tube shows too low a temperature when the flue gases pass out and too high a temperature when the air comes in, had been evident to me for quite some time, but not until about a year ago did I get an opportunity to demonstrate this fact.

Under the roof of a regenerator, next to the regular thermo-couple, I installed a fireclay sleeve filled with fireclay crumbs, in the center of which a thermo-couple was placed. A Roots blower, protected by a screen and a long pipe line, sucked flue gas or hot air through the firebrick crumbs, which, on account of their large surface and small mass, assumed the correct temperature almost instantly. I found differences of temperature between the regular pyrometer and the one imbedded in the firebrick crumbs amounting to more than 40 degrees. Of course, the method which I used is available for test runs of 6 to 10 hours only. After that time the voids

between the crumbs fill up with dust and slag particles, and it becomes impossible to suck the gases past the thermo-couple. Again I wish to say that the customary method gives values which are quite sufficient for supervision of the operation of furnaces, but that it is misleading if true gas and air temperatures are desired. This circumstance reminds me of a rather humorous incident. Nine or ten years ago, one of the subsidiary companies of the United States Steel Corporation had a very detailed heat balance made of a certain open-hearth furnace. Temperatures in the regenerator were measured or indicated by Mr. Chandler. One of the experimental engineers showed me the report, and it contained temperature data to one degree. Then I rather jokingly remarked that there was very little sense in giving temperatures in such detail and that round numbers might be preferable, because the values were, in my opinion, as much as 50° F. away from the truth. The experimental engineer replied in all seriousness, "You are right, Professor, but if we give the values in round numbers, the authorities in the downtown office will think that we are careless and do not know our business."

Mr. Chandler uses the value of 0.166 for specific heat of steel within the range of the test temperatures. This value is somewhat doubtful, and it is a pity that no accurate values for the specific heat of steel exist. The Bureau of Standards plans to make such determinations in the future, but does not know when it will be able to undertake that task. It appears to me that the American Iron and Steel Institute might do a service to its members by giving an order to the Bureau of Standards to do the work, and by footing the bill.

In looking over the test of the continuous recuperative furnaces, I miss a statement of the quantity of air delivered to the recuperator. That quantity is of interest, because it affords a means of checking the amount of leakage through and beyond the recuperator.

Leakage there is, and the amount is by no means negligible. From data on a test which was made about nine years ago on one of the furnaces investigated by Mr. Chandler, I computed that 30 per cent of the air entering the recuperator leaked out before it reached the burners; and in another Morgan furnace in the Pittsburgh district which was equipped with a tile recuperator, 65 per cent of the air leaked out. An analysis of the spent gases just ahead of the recuperator would shed further light on the subject. With the aid of these data, a heat balance of the recuperator could be made and information gained on the problems of how much of the air leaks through the recuperator and how much leaks out afterward.

That much air leakage exists is well known to the engineers of the Duquesne Steel Works, for they placed cast iron ducts in the brickwork leading from the recuperator to the burners in one of their furnaces about 6 years ago. The low preheat (about 400° F.) is probably due to leakage; a large weight of air, only part of which reaches the burners, is preheated to 400° F., whereas the correct weight of air might be preheated to 600° F. This is what the heat balance of the recuperator shows. The result of the heat balance is confirmed by tests on another Morgan furnace of practically the same dimensions for which I had the pleasure of doing the engineering. I placed the fan between the recuperator and the burners, sucking the air through the recuperator and leading it through an airtight insulated duct outside of the furnace from the recuperator to the burners. A preheat of 600° F. was easily obtained. It may be remarked that sucking the air through the recuperator reduces leakage by equalizing the pressure on both sides of the partition walls. The stack pulls on the flue-gas side, and the fan pulls on the air side. An additional advantage of the elimination of leakage is the reduction of the pressure drop through the recuperator; for, if only 70 per cent of the air formerly hoisted passes through the recuper-

ator, the pressure drop is only one-half of the former value.

When it comes to a comparison of thermal efficiencies between regenerative furnaces and continuous furnaces, it is quite evident that the two continuous furnaces tested by Mr. Chandler are more efficient at their particular rate of heating than the regenerative furnace is. But that need not be so in all cases, for in continuous furnaces

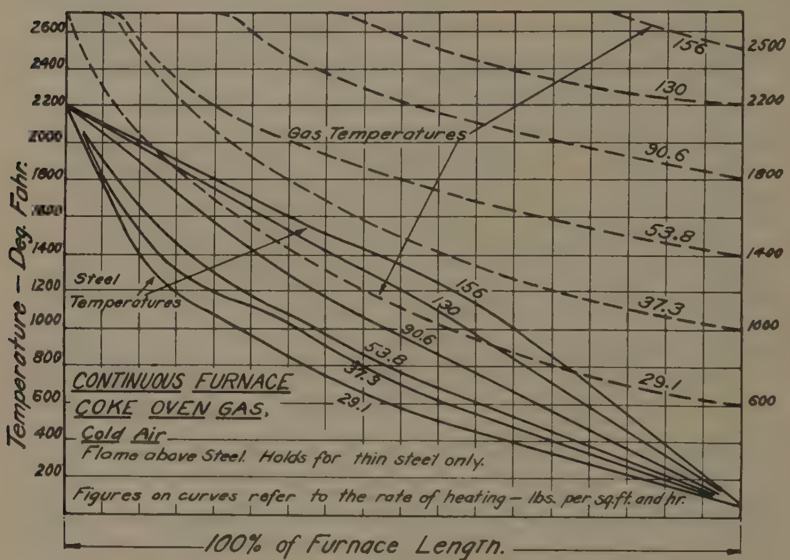

Fig. 1.

the fuel consumption per unit weight of steel heated varies with the rate of driving.

As far as I know, a complete theory of the continuous furnace had never been developed. Since I needed such a theory for my book on industrial furnaces, which is now in press, I had heat transfer calculations made for continuous furnaces which resulted in curves of which one example is shown in Fig. 1. In it the abscissæ represent path of travel of heated gases and of steel through the furnaces, while the ordinates are temperatures, the solid lines indicating steel temperatures, while

the broken lines are gas temperatures. The figures on the curves indicate the rate of heating in pounds of steel per square foot of hearth and per hour. In these calculations losses by radiation and convection were taken care of. From the data which were thus obtained the curves shown in Fig. 2 were plotted. Fig. 2 shows the heat required in the fuel per pound of steel heated as a function of the rate of heating, and, to another scale, the thermal efficiency of the furnace. The results of Mr. Chandler's tests have been entered. The coincidence between theory and tests is much better than

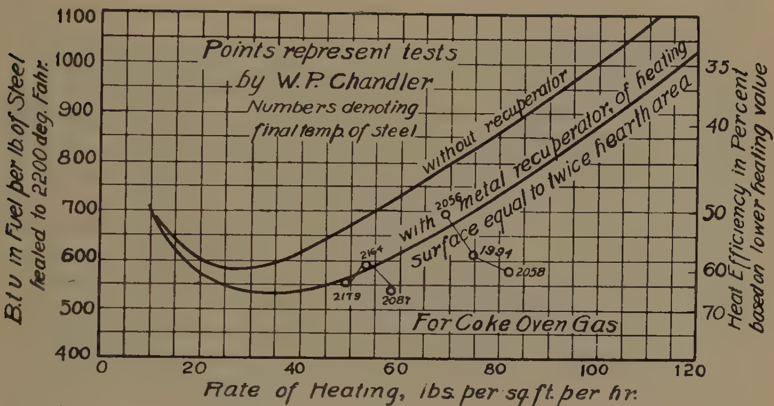

Fig. 2.

appears from the illustration, because the theory assumed that the steel would be heated to 2200° F., whereas the steel temperatures in Mr. Chandler's tests were all below that value. Furthermore, my figures did not consider a roof recuperator. The curves show that the efficiency of a continuous furnace drops if we drive it too hard, and that is the point I wish to bring out. If we heat very much steel per square foot of hearth and per hour in a continuous furnace, its efficiency drops below that of a regenerative furnace.

It should be noted that even if some of the test points were some distance away from the theoretical

curve, that fact would militate against the test rather than against the theory. Test data can be very misleading in furnaces, because a great deal of heat is stored up in the brickwork of the furnace. If the rate of heating is changed, the new condition of equilibrium is not reached until many hours later, the time depending upon the thickness of the brickwork. In view of the great possibilities for error, I consider the coincidence remarkably good. This fact is more strongly illustrated by Fig. 3 which contains a collection of furnace tests

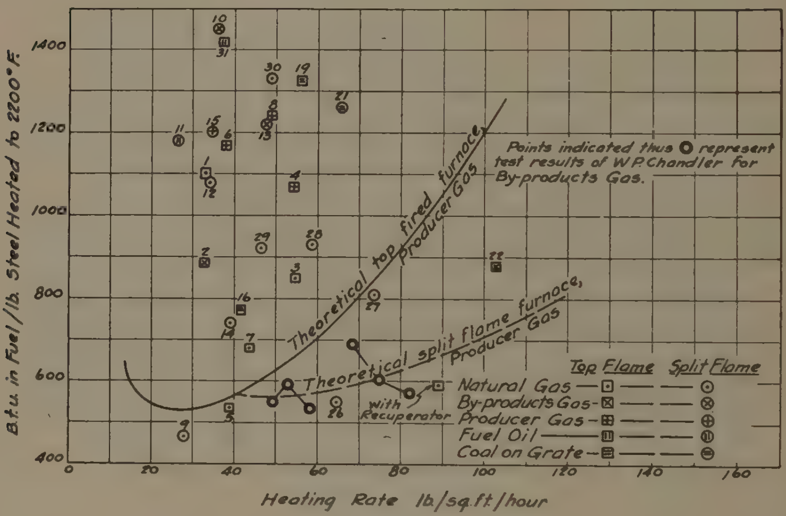

Fig. 3.

from various sources; as before, heat consumption has been plotted against rate of heating. Some of the heat consumptions are so great that they are a great distance above the limits of the illustration. The data here collected are in many cases overall figures, by which is meant that they are monthly statements of fuel consumption and steel heated. They include fuel consumption for warming the furnace, for keeping it hot during periods of mill trouble; they include periods of forced heating, and other periods of improper adjustment of

burners and of furnace damper. Thermal efficiencies during a test and over a long period are not necessarily alike; as a matter of fact, they seldom are alike.

In the planning of continuous furnaces for new mills, the perplexing question always is this: recuperator, or no recuperator? It is easy to get the same efficiency in a non-recuperative furnace which is obtained in a recuperative furnace simply by making it longer and insulating the additional part. Of course, added length may be objectionable. Some one said jokingly that in a continuous furnace, the difficulties increase with the cube of the length. In furnaces with end discharge the trouble due to added length is easily obviated by installing more furnaces. Many mill engineers are, for that reason, opposed to recuperators. However, the latter has one advantage, namely that with preheated air quicker combustion is obtained, less excess air is needed, and the furnace loss by scaling is reduced.

One more point should be brought out, namely, the interaction between the furnace and the mill. If the mill always produces the same section, and if there is no mill trouble, the furnace can be adjusted properly and can be let alone. In that case a sustained high efficiency can be obtained. If, on the other hand, the section varies, or if there is much mill trouble, it is next to impossible to maintain high furnace efficiency. This is particularly true for continuous furnaces with side discharge, because one and the same furnace is then required to heat a widely varying weight of steel in unit time. It should by right be designed for fast flow of gases and also for slow flow. If it is right for one, it is wrong for the other. As an example for this statement, I might mention that furnaces as described by Mr. Chandler are, at times, operated with holes in the back and in the roof for the purpose of allowing greater gas flow through the heating chamber.

For furnaces with variable rate of flow, a properly designed recuperator offers probably the best solution.

The question is, should it be a tile recuperator or a metallic recuperator? For very variable rates of heating a tile recuperator is exposed to the danger of cracking. For fast firing a metallic recuperator is objectionable to a certain extent, because it may burn out; but that danger can be eliminated by calorizing the metal and by providing a bleeder. Furthermore, replacement of the recuperator tubes in a Morgan furnace can be facilitated by making that arch of the roof, which lies over the recuperator, sectional and removable. This feature is a great help for other work also, such as replacing worn out skids which span the recuperator entrance.

As before stated, a preheat of 600° F. can readily be obtained with the present design of Morgan recuperator, but 800° F. or even 1,000° F. should be obtainable if the tubes are provided with fins like those of a motorcycle engine or of a Franklin automobile engine cylinder. The heating surface could be very much increased by this method. It is well known that the merchant mill at Gary has cast iron recuperators of the inverted U type and that a preheat of 1,000° F. is obtained without any trouble, but the recuperators lie under the hearth and are rather inaccessible. There should, however, be no difficulty in obtaining the same preheat by comparatively simple changes in the Morgan design.

There are a few more points in the paper of Mr. Chandler upon which a discussion may spread itself, but I am afraid that I have exhausted your patience. When I once get started upon the subject of heating furnaces, it is hard for me to find an end. Once more I wish to say that there should be more tests published like those contained in the paper of Mr. Chandler and that his paper renders a distinct service to the Institute.

Vice-President Topping: Further discussion of Mr. Chandler's paper will be given by Mr. W. B. Chapman, Chapman Engineering Company, Mt. Vernon, Ohio.

Discussion by William B. Chapman

Chapman Engineering Company, Mount Vernon, Ohio

Mr. Chandler has made an important contribution of accurate data on rolling mill furnace operation at Duquesne. Papers of this kind are of great value in stimulating fuel economy throughout the country.

In the first part of his paper Mr. Chandler states that "the most important factor governing the use of gaseous fuel is the maintenance of a constant pressure on the burner valves." In 1906 we designed an automatic regulator to serve this purpose for an alkali works in Saltville, Va. It saved enough to pay for itself in a couple of weeks and is still in operation. We thought at that time that all users of producer gas would want some such device within a couple of years, but in the 16 years that have elapsed since then probably less than 100 plants have installed automatic pressure-regulating valves for their gas producers. It should be done more generally, for Mr. Chandler is right.

Mr. Chandler gives an interesting table of the comparative allowable prices of fuels, showing that, if the price of natural gas is 30 cents per thousand cubic feet, one can afford to pay the following prices for other fuels: by-product gas, 15 7/10 cents; by-product tar, 4 4/10 cents; fuel oil, 4 cents; coal for producer gas, $6.04. Taking the same proportions and assuming that coal for producer gas can be had for $5.00, we then find that one can not afford to pay more than the following for the other fuels: natural gas, 24 9/10 cents; by-product gas, 13 cents; by-product tar, 3 7/10 cents; fuel oil, 3 3/10 cents. In these figures Mr. Chandler says he has not included interest and depreciation, but his estimate of $1.60 per ton for the cost of gasifying coal in gas producers is large enough to include all the overhead expenses of every kind if the gas plant is a modern one having a capacity of three or more producers. Hence, if a new installation is being considered, the above figure can be taken as the full cost

Fig. 1—Continuous recuperative heating furnace installation

of making producer gas,—excepting of course the cost of the coal.

Taking up the question of furnace design, we wish first to correct a few inaccurate generalizations due no doubt to assuming that the Duquesne furnaces and furnace practice may be taken as representing general practice elsewhere. Mr. Chandler says that in the continuous furnace "only the top of the billet is exposed and thus available for absorbing heat" and from this premise he argues that the billet must therefore remain longer in a continuous furnace than in a non-continuous furnace and that the billets must be smaller. But in almost all continuous furnaces (excepting those in which the billets have a very small cross section as at Duquesne) the billets rest on skids located high enough up so that at least one-third of the flame passes under the billets. He specifies a 5″x5″ billet as about as large as is practical to use in a continuous furnace. This is quite true for furnaces of the type he describes which only heat the billets from one side, but there is no such limit in a continuous furnace in which the proper proportion of gases pass under the skids. We have records of continuous furnaces heating ingots as large as 17″ square where the average fuel consumption per week is frequently under 150 pounds to the ton.

Mr. Chandler shows a much greater efficiency for the continuous furnace and explains it by the progressive movement of the steel through the furnace, while the gases travel in the opposite direction. This however is not a complete explanation. One reason why the continuous furnace is more efficient is because the billets are closer together and hence at the hot end (which is the end that counts), there are less square feet of radiating surface in the furnace roof and walls per billet heated than in a non-continuous furnace, in which the billets must necessarily be some distance apart.

We quite agree with Mr. Chandler's main conclusion, namely, that "the development of heating furnaces should

be along the lines of continuous recuperative furnaces,'' for his tests show that the recuperative furnaces are operating with 32% less fuel per ton of steel than the non-recuperative, but we do not agree that this development should be along the lines he suggests, viz., ''a metal recuperator with pipes or tubes similar to water-tube boilers.'' The reason we object to a metal recuperator is because the air can not be heated as hot in it as in a properly constructed tile recuperator made of the best fire

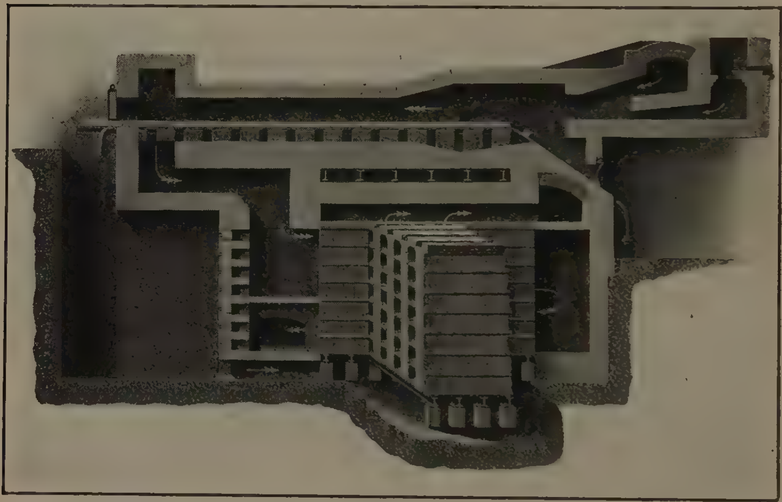

Fig. 2—Showing interior of continuous end-discharge recuperative heating furnace with tile recuperator

clay, and it is obvious that that recuperator is best which will heat the air hottest for a considerable number of years. The safe temperature for preheating the air in metal recuperators is about 400°F., as shown by the practice at Duquesne and elsewhere, for iron will not stand up long under high temperatures.

Fig. 1 shows a continuous slab heating furnace at the Youngstown Sheet & Tube Co., in which the air is heated to 1300°F. in a special tile recuperator. In certain types of furnaces, where the waste gases leave the hearth at a considerably higher temperature than is possible in a con-

tinuous push furnace, the air can be preheated to 1900°F. with this type of recuperator; and in spite of the high

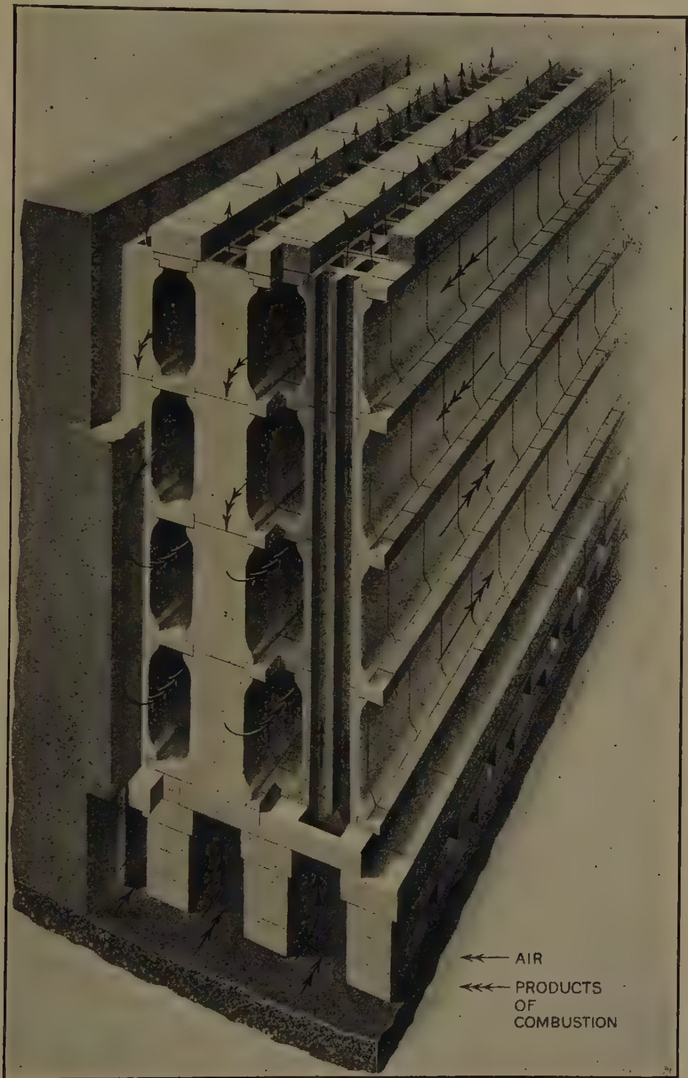

Fig. 3—Showing detail of arrangement of tiles in tile recuperator

temperatures no repairs are required in the recuperator. We have had similar recuperators in operation for two years in this country and have seen several hundred in

Europe that have been in operation nearly ten years without requiring repairs on account of leakage or breakage.

The success of this recuperator is due to a balanced draft that is automatically maintained between the air inside of the tile and the spent gases around the tile. The horizontal spent gas passages are designed and figured so that the suction required will not exceed 3/16″ of water and often not over ⅛″, while the vertical air passages are designed so that the natural rush of the air upward through the hundreds of little chimneys will automatically make a suction of 1/10″ to ⅛″ of water at the bottom of the recuperator and a constant pressure of about half that amount in the furnace. No fan is ever required to force the air through this type of recuperator as it is designed so that a large excess of air can be had in the furnace at any time by merely opening the air damper (which is usually kept two-thirds closed) at the bottom of the recuperator.

The interior of the furnace and of the recuperator is shown in the accompanying illustrations. The two furnaces are taking the place of five flat-hearth reversing furnaces formerly used to heat the 3″ to 4″ thick slabs required for this mill. The old practice was about 270 pounds of coal (in the form of producer gas) to the ton of steel heated; the present practice is as low as 170 pounds of coal per ton. In this connection it would be unfair to compare a side discharge furnace with an end discharge (as in this case), nor would it be fair to compare a narrow continuous furnace 5 or 6 feet wide, or even one 10 or 12 feet wide, with a double row of billets in it, as in the accompanying illustration, with a wide or nearly square furnace charged with billets 30 feet long—as at Duquesne; for a wide or square continuous furnace has far less radiating surface per ton of capacity than a narrow furnace, or one with a double row of billets.

The following table shows the theoretical saving to be derived from preheating the air when various kinds of fuel are used assuming the excess air in one case to be

20% and in the other case 80%. The actual saving is greater than the theoretical because the hotter the air the better the combustion and hence less excess air is required.

APPROXIMATE PER CENT. OF FUEL SAVING MADE POSSIBLE WITH DIFFERENT FUELS BY PREHEATING THE AIR TO DIFFERENT DEGREES. CALCULATED BY A. D. WILLIAMS.

Kind of Fuel	Excess Air, Per Cent.	Amount of Preheat, °C., and Equivalent °F.					
		200° C. 392° F.	400° C. 752° F.	600° C. 1112° F.	800° C. 1472° F.	1000° C. 1832° F.	1200° C. 2192° F.
Pulverized coal...	20	6	11½	16½	21	25½	30
Producer gas.....	20	6½	12½	17½	22½	27	31
Coke oven gas....	20	7	13	19	24½	29	33
Fuel oil*.........	20	7½	14	19½	25	30	34
Natural gas......	20	8	15	21	26	31½	35½
Producer gas†....	20	10	17½	24	30	35½	41
Pulverized coal...	80	9	17	24	30½	36½	40½
Coke oven gas....	80	10½	19	26	32½	38	43
Fuel oil*.........	80	11	19½	26½	33	39	44
Producer gas.....	80	11	20	27	34	40	45
Natural gas......	80	11	20½	28	35	40½	45½
Producer gas†....	80	13½	24	33	39	45½	51

*Mechanically atomized, no steam used.
†Both gas and air preheated.

Mr. Chandler suggests placing the recuperator above the furnace instead of below it. This would be wrong both in theory and practice. Probably the best known authority on furnace design is the Russian Engineer Groume Grg'imailo. In his exhaustive work on this subject, the English translation of which is about to appear, he makes it very clear that the only efficient way to make gases give up their heat is to cause them to descend so that such portions of the gases as come in contact with cool surfaces and become chilled will descend more rapidly because of their increased weight. In this way the coolest gases work down and out first. Reciprocally the most efficient way to heat air is in an ascending column. The hottest portions will rise faster leaving the cooler portions behind until all is equally heated. Such an arrangement of a heat interchanger is quite impossible when the

recuperator is located over the furnace. Moreover, if the recuperator is located below the furnace the radiation from its walls bathes the furnace above it in warm air, thus reducing radiation losses, which are always the largest losses in either a regenerative or a recuperative furnace.

In designing continuous furnaces the greatest gain in efficiency is not made by lengthening the furnace so as to make the cool end cooler but by preheating the air so as to make the hot end hotter. The proper place to utilize heat is at the hot end, not the cold. This is due to the fact that furnaces are very slow and the radiation losses correspondingly large if the flame temperature is not considerably in excess of the temperature required in the steel. For example, if the steel had to be heated to 2200°F. in a furnace having a flame temperature of but 2400°F. the furnace would be slow and inefficient, while if the air could be preheated so that a flame temperature of 2800°F. could be obtained the furnace would be nearly three times as fast and much more efficient.

In the six tests given by Mr. Chandler of the recuperative furnaces the average temperature of the spent gases entering the recuperators was 1177°F. and the average temperature of the preheated air at the burners was 416°F., a difference of 761°F. With a properly designed tile recuperator the air can be heated to within 300°F. of the temperature of the spent gases entering the recuperator and the efficiency increased accordingly. We would like to see what records could be obtained at Duquesne with all their advantage of skill and full-capacity loads if the air instead of being heated to 416°F. were heated to three times that temperature—as it could be.

Vice-President Topping: The next paper is The Use of Liquid Fuel in Metallurgical Furnaces, by Mr. R. C. Helm, director, physical laboratory, American Steel & Wire Company, Worcester, Mass.

USE OF LIQUID FUEL IN METALLURGICAL FURNACES

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With the variations in economic conditions which have existed in different localities in the past few years, as regards the status of coal converted into producer gas for use in metallurgical furnaces, an added impetus has been given to the study of the proper application of various types of liquid fuels where such fuels were available at prices which would permit of their economic use. Tar and fuel oil are the most common of the liquid fuels which are economically available for use in metallurgical furnaces and this paper has, therefore, been confined to their use only.

The use of oil as a fuel in furnaces for metallurgical purposes dates back a good many years, and the demand for it is constantly increasing. Originally, the oil was used in its crude form without the removal of any of the more volatile hydrocarbons. Naturally, the low flash point of such oils made them unsafe to handle. Moreover, the development of wider uses for these lighter oils demanded their extraction from the crude. The removal of these lighter hydrocarbons raised the flash point of the residue considerably, giving a resultant product which could be used with more safety. A large proportion of the oil now used as fuel is obtained as a residue in this manner, although some residues are so viscous and of such poor quality as to make them unsuitable for economic use. Other types of fuel oil developed from more complete refining operations are also adaptable for fuel purposes in metallurgical furnaces.

The calorific value of the fuel oils in common use varies from about 141,800 to 152,400 B.T.U. per gallon with corresponding density as measured by the Beaumé hydrometer of 30° to 12° at a temperature of 60° F. As oil is purchased by the gallon, the heavier but more viscous fuel oils, therefore, have the higher thermal values. The thermal value of the oil, however, does not necessarily indicate its adaptability for furnace use, as other features such as the content of impurities and size of furnace installation must be taken into consideration in deciding whether the heavy and more viscous oils should be used in preference to the lighter and more fluid oils.

Specifications under which fuel oils are purchased, usually require that the fuel oil shall not contain over one per cent of water and foreign matter, which are likely to interfere with the use of the oil due to clogging of burners and interference with the operation of valves. It is commonly agreed that the flash point should not be less than 150° F. (closed cup) as a matter of safety, although oils with a lower flash point are being used. Specifications for viscosity will vary dependent on the arrangement of the system used for conveying the oil from storage to the burner. The sulphur content of fuel oil, which may run as high as 4.0 per cent in some oils, is of great importance when used in connection with very high temperatures, such as are obtained in open-hearth practice, where the products of combustion come into direct contact with the charge during the melting down period. Under these circumstances, the percentages of sulphur may have to be limited in specification to 0.75 per cent or less depending on the open-hearth practice used. However, in certain localities, the less cost of high sulphur fuel oils as compared with low sulphur fuel oils has led to the development of an open-hearth practice whereby limited percentages of high sulphur oils can be used without detrimental effect to the finished product. With such a practice, specifications may be more liberal with respect

to limiting the percentage of sulphur allowed in the fuel oil.

The introduction of the by-product coke plant increased the available amount of coal tar to such an extent as to result in making coal tar available as a liquid fuel for use in metallurgical furnaces. In addition to tar, the by-product coke plant also furnished a supply of gas for the same purpose. The usual proximity of the by-product coke oven plant to the open-hearth plant supplies a very good opportunity of utilizing both coke oven gas and tar as open-hearth fuel to the economic benefit of both plants.

As the production of tar goes hand in hand with the production of gas, the natural development of the use of both these fuels has resulted in the practice of using them in combination as fuel for the open-hearth furnace. The use of coal tar only has also been advantageously developed. As tar can be burned more advantageously where high temperatures are required, its use in steel plants has been chiefly confined to open-hearth practice.

Tar has a thermal capacity of about 155,000 to 162,000 B.T.U. per gallon. Coke oven gas as used is debenzolated and has a thermal capacity averaging 540 B.T.U. per cubic foot.

Many types of furnaces for metallurgical use have been equipped for use of liquid fuels. As far as the supply of air for combustion with liquid fuel is concerned, these types may be classified into three groups: (1) non-preheating furnaces in which the air is admitted to the combustion chamber at atmospheric temperatures; (2) regenerative furnaces operating on the reversing principle in which the air is preheated in a checker chamber before entering the combustion chamber, the checker chamber deriving its heat from the waste gases; and (3) recuperative furnaces in which the air for combustion is preheated by passing through a set of flues which alternate with flues through which the hot waste gases flow in a counter direction or at right angles to the direction of flow of the air.

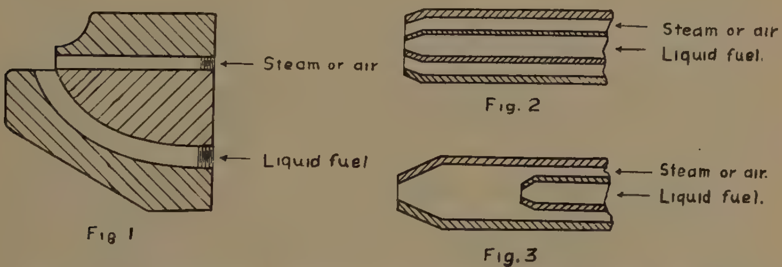
While the use of liquid fuel has been adopted as a matter of expediency in some cases, the range of application includes open hearth, crucible, soaking pit, billet heating, forge, annealing, hardening and tempering furnaces; and a variety of furnaces for special heat treating operations. The use is also extended to a variety of furnaces used in the non-ferrous metal industry. The scope of this paper has been restricted to cover chiefly the use of liquid fuels in open-hearth furnaces and in furnaces particularly adapted to use in the wire drawing industry.

The use of coal tar and the heavier oils of 12° to 20° Bé. requires careful heating of the oil in supply tanks so that they can be sufficiently reduced in viscosity to enable them to be pumped to the burner at the furnace. As heating vaporizes any light oils present, tanks should be vented at the top to permit of their removal from the system. The lighter oils having a density of 20° to 30° Bé. are sufficiently fluid so that they may be pumped to the burner with little heating except in particularly cold weather. Heating of tar and heavy fuel oil is also essential in order to obtain proper atomizing of the oil at the furnace. Failure to provide sufficient heat to heavy fuel oil or tar cannot help but result in unsatisfactory results from the furnace in which it is used due to the failure of the burner to perform its proper function.

After bringing the liquid fuel to the furnace under suitable temperature for atomizing, the success of using it depends on burner design, furnace construction, and the proper application of the burner to the furnace, so that the thermal value of the liquid fuel may be utilized at the proper time with the highest efficiency to produce the results required. For obtaining the highest thermal efficiency, it is necessary that burners be designed so that they will break up or atomize the liquid fuel into very minute parts in order that the greatest amount of surface may be offered to the air required for combustion.

In order to accomplish this purpose, many kinds of

burners have been designed for private use or patented and placed on the market for general furnace use. These types of burners are intended to accomplish atomization by, (1) mechanically breaking up the liquid fuel into minute particles; (2) by breaking up the liquid fuel with an air or steam spray; and (3) by vaporizing. Attempts made to apply the last mentioned process to fuel oil by superheating to a temperature sufficient for vaporizing have not as yet been demonstrated as practicable due to the deposition of solid coke in the vaporizing chambers with consequent clogging of the system. Mechanical atomization, while practiced to a very large extent with steam boilers, has unfortunately not been developed for



Figs. 1 to 3—Showing the principle used in some types of liquid fuel burners.

general application to metallurgical furnaces. Burners which find extensive use in metallurgical furnaces, however, are those types which accomplish atomization by spraying either with steam or compressed air under variable pressures dependent on furnace requirements.

There is quite a large field for using different principles in varying the design of burners which depend on steam or compressed air for atomizing the liquid fuel. A few of the principles which have been used in burner design will be described and illustrated so that a general idea may be obtained of the possibilities for variation. Atomizing burners are generally classified in two groups, one of which accomplishes atomization outside the burner, the other inside the burner. Fig. 1 illustrates a very

simple arrangement whereby the steam or air jet passes directly over the oil jet, creating a suction effect which assists in the efficiency of atomizing outside the burner. Fig. 2 illustrates another principle in common use where the oil is supplied through a central pipe to the tip of the burner. The steam supply running also to the tip of the burner surrounds the oil supply line. Atomizing is, therefore, accomplished externally in the furnace. Fig. 3 shows a burner with a chamber beyond the end of the fuel nozzle and provides for atomizing before the fuel enters the furnace. This type of burner may be altered so that the air and oil chamber has a Venturi shape and is known as the injection type. This principle is used with the idea of obtaining velocity in assisting to atomize the liquid fuel. Either steam or air may be used for atomizing with any of these general types of burners. The shape of the nozzle may be round or flattened in almost any type of burner to meet the requirements of furnaces for special purposes.

The pressure of air or steam required for atomizing with any burner is dependent on the furnace design and the character of the liquid fuel. Air pressures for the lighter oils may be as low as a few ounces per square inch where small furnaces are used. With the heavier liquid fuels, where steam is commonly used, the pressure on the line may run as high as 140 pounds per square inch.

Use of Liquid Fuels in Open-Hearth Furnaces

The price of fuel oils in localities where large tonnages of open-hearth steels are produced is usually so high as to prohibit its use in competition with producer gas. The supply of by-product coke oven coal tar, however, ranging in quantity with different kinds of coal from approximately five to thirteen gallons per ton of coal used, is available in sufficient quantities and at prices which make its use economically attractive, as far as the supply lasts, for use either alone or in combination with coke oven gas

in open-hearth furnaces. Where the open-hearth practice has been developed for the use of tar alone or in combination with coke oven gas with consequent closing down of the gas producers, fuel oil may be substituted for tar to permit continuous furnace operations if the regular supply of coal tar is interrupted for short periods of time. As the equipment necessary for using tar is similar to that used for oil, such a change may be quickly accomplished. It is a good plan, however, when making such a change to clean out the system with steam under high pressure in order to free the pipes of any carbonaceous deposits which may have collected in them.

Installations of special equipment for handling liquid fuels are required, the cost of such equipment, however, being comparatively moderate. Storage tanks of variable capacity will be required to meet the demands of the individual plant. The use of large storage tanks at by-product coke oven plants, however, makes it unnecessary to provide large tank installations at the open-hearth plant. Where fuel oil is depended upon alone, possible delays in transportation due to distance from supply stations may necessitate very large storage tanks for even moderate sized open-hearth installations. All storage tanks for tar and the heavier fuel oils must be equipped with internal steam coils in order to supply sufficient heat to decrease its viscosity to such an extent that it may be readily pumped through the furnace supply pipes and be better atomized at the burner. The installation of a regulator in the steam line is of considerable benefit in maintaining proper temperature. The temperature of the tar in the tank found most desirable in practice varies from 125° to 150° F. The temperature used for pumping and free circulation of heavy fuel oils is usually around 160° F. Higher temperatures tend toward the deposition of hydrocarbon which may cause clogging of the burner. Lower temperatures cause poor atomization and, therefore, dripping at the burner with consequent loss of thermal value.

When unloading from tank cars, strainers for removing solid mechanical impurities are placed in the pipe line to the tanks if unloading is accomplished by gravity or in the suction line of pumps when it is necessary to use the latter means of unloading. Such straining is usually through baskets of 3/16″ mesh screens, set in suitable castings in the pipe line.

The liquid fuel is pumped from the supply tanks through pipes to the various furnaces. Pumps installed for this purpose are of both the duplex and triplex type, governed to maintain a steady pressure on the line. Where trouble is experienced with pulsations, relief is sometimes found by applying compressed air directly to the tank. All pumping equipment should be in duplicate in order to prevent serious delays in furnace operation during periods when it is necessary to make repairs to the pumps. When steam is depended upon for pumping, an auxiliary electrically driven pump will provide additional flexibility in case of breakdown or vice versa.

In order to convey tar and the more viscous fuel oils to the furnaces, pipe lines are arranged so that, after the various furnaces have been supplied, the line is returned to the pump. It is necessary in some cases to pump as much as fifty per cent more fuel than is actually consumed by the furnaces. Both the supply and return lines should be run parallel with a steam line and the three enclosed with a heavy asbestos covering to prevent cooling of the fuel during circulation. The size of lines for the fuel should usually not be less than three inches in diameter as smaller lines cause too much restriction to oil flow. Since storage tanks are generally isolated from the open-hearth building, it may be necessary to reheat the fuel as soon as it enters the building. A steam jacketed heater is satisfactory for this purpose. Reheating of the liquid fuel with a similar steam heater may also be necessary at the furnace, before the fuel enters the burner.

A practice whereby a limited amount of cheaper high sulphur fuel oil may be used in connection with the more

costly low sulphur oil without detriment to the quality of the finished product has been in use for a number of years at an open-hearth plant in the east where the cost of fuel oil justifies its entire use in preference to producer gas. The high sulphur oil obtainable has a density averaging about 15° Bé. and is handled through a circulating oil system as described above. This oil is circulated at about 150° to 160° F. The low sulphur oil, averaging 25° Bé. and being considerably less viscous, is supplied to the furnaces through one pipe line which is dead ended after supplying the last furnace in the system. The temperature of the lighter oil at the pumping station varies from about 90° to 100° F. The furnaces are

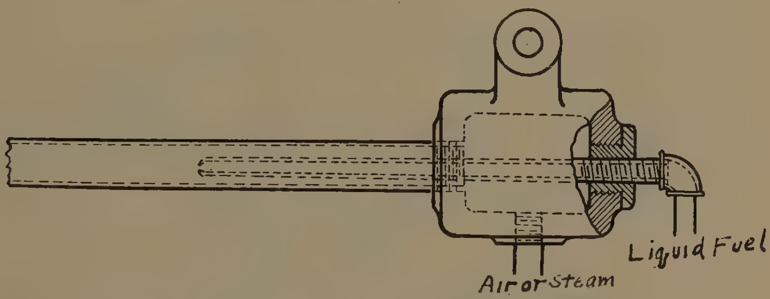


Fig. 4—Liquid fuel burner for open-hearth furnace.

operating entirely with a cold pig iron and scrap practice. During melting down of the charge, low sulphur oil is used entirely. After the slag completely covers the charge, high sulphur oil is used for the completion of the heat. The furnace supply lines for both the high and low sulphur oils are brought together just before reaching the three-way reversing valve. Valves for shutting off either the high or low sulphur oils, as the practice demands, are conveniently arranged in the separate oil lines just before the two supply lines are joined.

As tar is more difficult to atomize than even the heavier fuel oils, the type of burner used is worthy of considerable attention. The most common type of burner used for atomizing tar is illustrated in Fig. 4, where the

tar is introduced through a central nozzle with the steam chamber entirely surrounding it. With burners of this type, various alterations of design have been tried with the idea of increasing the efficiency of atomization by inserting a valve spindle through the tar supply pipe, and attaching a ball or cone to the spindle at the fuel orifice. The ball or cone diverts the tar directly into the path of the steam giving better opportunity for atomization. Another modification of this burner may be obtained by plugging the end of the nozzle and drilling holes at various points throughout its circumference through which the liquid fuel is forced into the path of the steam.

Fig. 5 illustrates a burner, designed and patented by

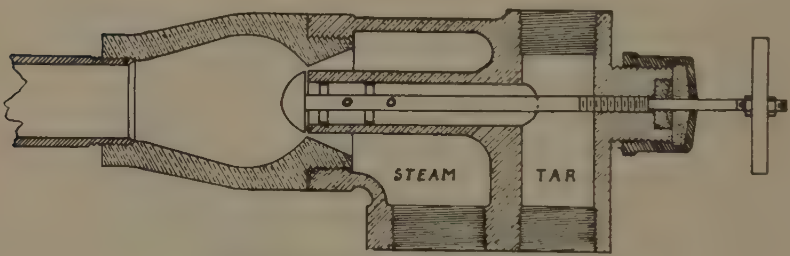


Fig. 5—Krause burner for liquid fuel.

Mr. Krause of the South Chicago plant of the Illinois Steel Company, intended primarily for increasing the efficiency of atomization when burning tar. Its construction lends itself readily, however, to the application of atomizing fuel oils with great efficiency. It is quite simple in design but very effective in atomizing tar. The tar supply passes through the central part of the valve to the button at the end of the valve stem where it is sprayed in fan shape into the path of the steam. Small projections from the valve stem to the wall of the valve prevent vibrations. The steam chamber is conicled in the direction of the tar outlet so that maximum velocity is obtained at the area of contact between the tar and oil. The atomization of the tar accomplished in this burner proves very effectual as judged by combustion conditions within the

furnace. The burner also has the advantage of being quickly cleaned by screwing the valve stem in or out if clogging occurs at the tar orifice.

The steam pressure on the line supplying steam for atomization varies from 50 to 125 pounds per square inch, dependent on furnaces and burner construction. Likewise, the amount of steam per gallon of oil atomized varies from about three to six pounds. Dry steam is essential for good atomization, steam separators being used where necessary at advantageous positions on the line to obtain this condition. While the amount of steam seems relatively small, it is an item which should not be neglected in determining the type of burner to be used. Compressed air has not proven satisfactory for the atomization of tar. As fuel oils can be atomized with compressed air, however, tests have been conducted at an open-hearth plant using fuel oil only to determine whether steam or compressed air was cheaper. Such tests showed a net saving of seven per cent in the amount of fuel oil consumed in favor of compressed air, using a type of burner found to give consistently good results in furnace operation.

With the temperature conditions existing on the ends of an open-hearth furnace, it is necessary to provide some means of preventing the burner from being destroyed. This may be accomplished by providing mechanical means of swinging the burner out of the furnace when not in use; by placing the burner within a water jacket; or by building a tunnel, which may or may not be water jacketed, into the end of the furnace. As the majority of open-hearth furnaces on which liquid fuels are now used were designed primarily for the use of producer gas, there is commonly not sufficient space between furnaces to permit of the use of swinging burners.

In cases where tar is to be used in combination with coke oven gas and the introduction of both fuels has been found to give the best results when admitted into the end of the furnace, the gas burner and tar burner are

combined in the same water jacket as illustrated in Fig. 6. Coke oven gas, due to being very light, is always introduced under the tar or oil, the heavier liquid fuel acting as a blanket to keep the lighter gas from rising and burning at the roof of the furnace with consequent short life of the furnace roof. The objection to using a burner of this type is that the tar and steam both must

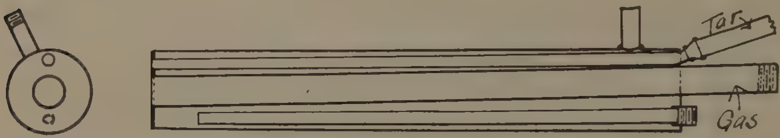


Fig. 6—Combination water-cooled tar and coke oven gas burner.

pass through a long atomizing chamber surrounded with water. The cooling effect of the water tends towards both condensation of the steam and liquefaction of the tar. The shape of the gas tip used with the combination coke oven gas and tar burners is either round or flattened. As the details of furnace construction vary, it will be necessary to determine by experiment whether the coke

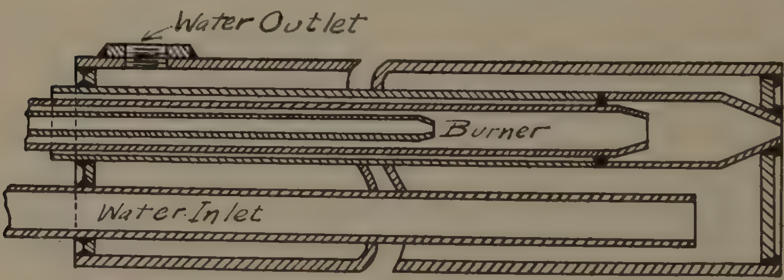


Fig. 7—Water-jacketed liquid fuel burner.

oven gas will give better results with either the round or flattened nozzle.

With furnaces designed for introducing tar alone at the ends of the furnace, a water jacketed burner similar to that illustrated in Fig. 7 may be used. This type of burner does not possess the objectionable feature of bringing the burner chamber in direct contact with the

cooling water. A similarly designed water jacket may also be used in connection with the combination tar and coke oven gas burner.

A brick tunnel may be built into the furnace from the end wall as shown in Fig. 8. The high temperatures existing in the furnace may necessitate water-cooling in order to insure necessary life of the tunnel. In some furnaces, however, using fuel oil and having a tunnel similar to that shown in Fig. 8, a small amount of steam,

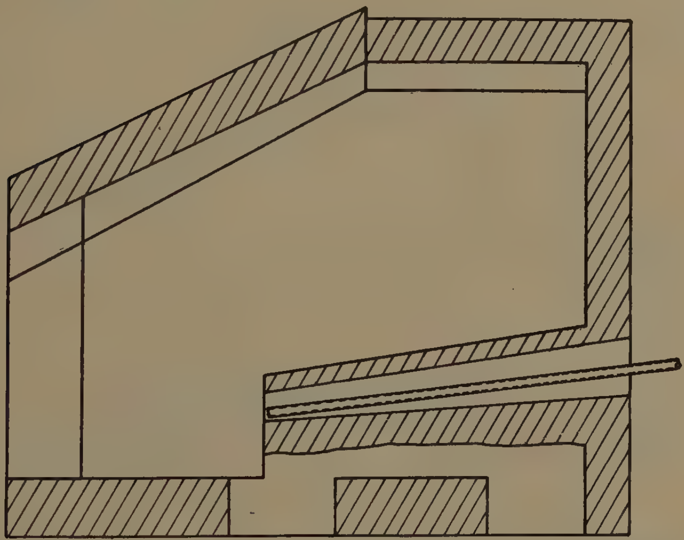


Fig. 8—Oil burner in brick tunnel through end of open-hearth furnace.

insufficient to interfere with furnace operation, is kept passing through the unused burner, neither burner or tunnel being water-cooled.

The extent to which changes in design of furnace ends is justifiable is in a measure determined by the quantity and type of liquid fuel available. Fig. 9 illustrates a method used for introducing a tar or oil burner into the end of a furnace designed for use with producer gas. Other features of furnace design may require the burner to be introduced so that its tip partly extends into the gas port, instead of taking the position shown

in Fig. 9. In very large furnaces, better fuel distribution may at times be had by using two burners on each end of the furnace, each burner being located toward the side wall of the furnace.

Where a steady supply of liquid fuel is available, the construction of the furnace ends may be considerably simplified as illustrated in Fig. 10. With this design, the air for combustion is admitted through two uptakes at the corners of the furnace and the cinder pockets are combined into one chamber. Both checker chambers at each end of the furnace are utilized for heating the air.

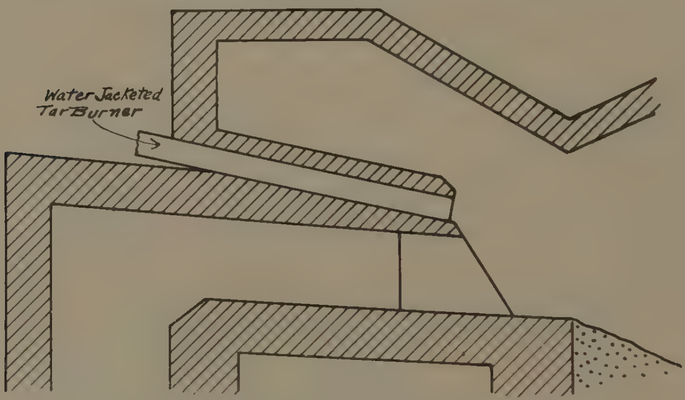


Fig. 9—Tar burner in producer gas furnace.

Fig. 8 shows the modification of port construction applied to a 50-ton oil burning tilting furnace.

The location of the burner in the furnace for either tar or fuel oil is of great importance, and in practice differs as to the height above and angle which it makes with the bath line and the length introduced into the furnace. It should be placed so that luminosity is obtained as soon as the fuel reaches the furnace hearth. In connection with this, it is important that the burner be so placed and the port ends so constructed that proper direction of atomized fuel and air for combustion will give the most efficient melting down and prevent melting of the roof. As different types of burners vary in the

thoroughness of atomization, the type of burner used will have some bearing on its location.

The use of a satisfactory quality of liquid fuel alone requires little or no changes in open-hearth practice. It has been used with furnaces up to 200 tons capacity. The quantity of fuel consumed per ton of ingots produced will, however, vary according to the open-hearth practice used at different localities. Furnaces operating with a combination coal tar and coke oven gas practice use

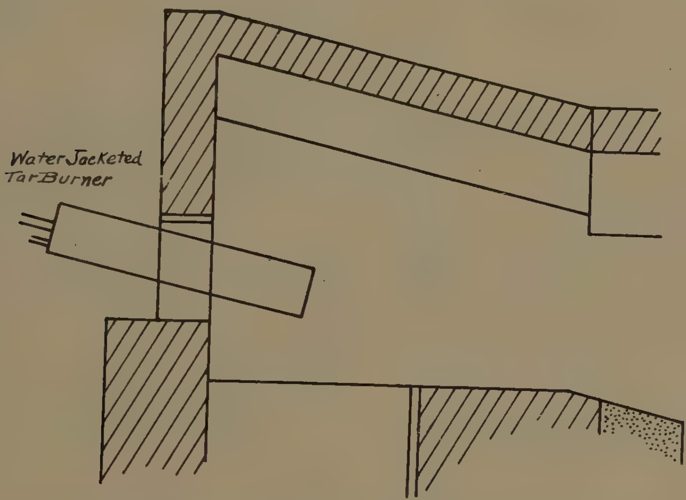


Fig. 10—Design of open-hearth furnace end for tar burning.

variable percentages of each dependent on local conditions. Commonly, however, about fifty per cent of the heat required is derived from each source. Some plants have experienced a reduction of 10 to 15 per cent in the time of heats under similar conditions and a reduction in furnace repairs, as compared with furnaces operating with producer gas. Where waste heat boilers are installed, the less volume of gases from liquid fuel burning, as compared with furnaces operating with producer gas, results in a less amount of heat available for use in the boilers.

Application of Liquid Fuel to Heat Treatment of Wire Products

Fuel oil has proven of considerable value in its application to furnaces used in the continuous heat treatments of both high and low carbon steel rods or wire. The heat treatments in common use in the production of steel wires are patenting, hardening and tempering, and annealing. The two latter treatments mentioned are quite familiar. The patenting process, however, finds its chief commercial application throughout the wire producing industry. A brief discussion of the patenting

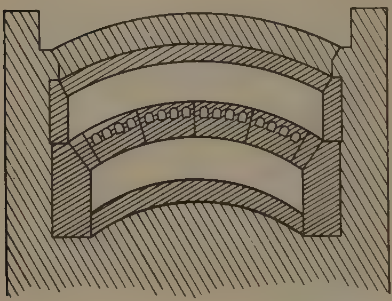


Fig. 11—Cross section of earlier type of coal fired, old process patenting furnace.

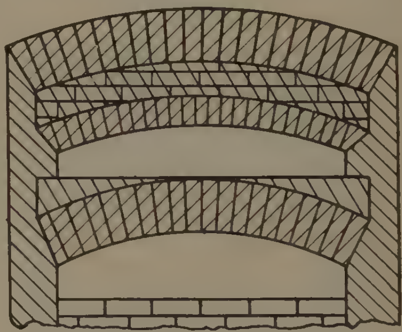


Fig. 12—Later design of coal fired, old process patenting furnace.

process will serve to indicate the adaptability of fuel oil to the furnaces required to carry on this heat treatment. The patenting process is intended to impart to the wire an uniform degree of toughness and temper which will permit of drawing the wire through dies to obtain the proper size and quality demanded for various commercial purposes. The patenting process of wire is accomplished by two general methods. One of these types is known as old process patenting, in which the wire or rod is continuously passed through a furnace, where it is required to reach a temperature of approximately 1,700° F., after which it passes out of the furnace, through unrestricted air space, to be again wound on

reels to facilitate handling. The second type of patenting is known as double lead patenting, in which the wire or rod is passed continuously through a hot metal bath, usually lead, where it is heated above its critical temperature and passes immediately into another lead bath having a temperature below the critical temperature of the steel. Each of these processes has its particular use in the production of various grades of wire for definite commercial uses. The double lead process, however, on account of obtaining better temperature control surpasses in permitting the production of high carbon wires of great strength and toughness.

With the introduction of old process patenting to the wire industry, furnaces were generally designed for the use of coal, except where natural gas was available, and coal fired furnaces for this purpose are still used where economic conditions are favorable. The process requires that a large tonnage of cold rods or wire pass through the furnace and exit at comparatively uniform temperatures. Early furnace designs, such as illustrated in the furnace cross section of Fig. 11 provided for a large amount of brick work which acted as a reservoir for radiating heat to the rods or wire as they passed through the tubes. Heat was supplied from a coal fire at the end of the furnace, the gases passing under the tube brick arch to the opposite end of the furnace, returning the full length of the furnace over the top of the tubes and then passing to the flues. A later development of the furnace is shown in Fig. 12 and eliminates the tube brick arch, providing, therefore, for the passage of the wire directly through the furnace gases. While the latter design reduced the cost of coal per ton of product, furnace temperature control was no better than with the original type of furnace and the possibility for fluctuations of temperature during cleaning of fires still existed. By using fuel oil, furnace designs for old process patenting could be readily varied in order to utilize the full effects of the heat of combustion at a

position in the furnace which would most favor thorough heating of the wire or rods to the desired temperature. The design of a patenting furnace in which very efficient heat treatment is performed is illustrated in Fig. 13. The arch in the furnace is somewhat similar to that of a longitudinally bisected frustum of a cone, using the bisected plane as a base. The burner is introduced in the end of the furnace at the narrow end of the cone and is of the type illustrated in Fig. 2 with a nozzle of sufficient length to extend within the furnace wall. Air for combustion is admitted around the burner. Dry steam under 125 pounds pressure is used for atomiza-

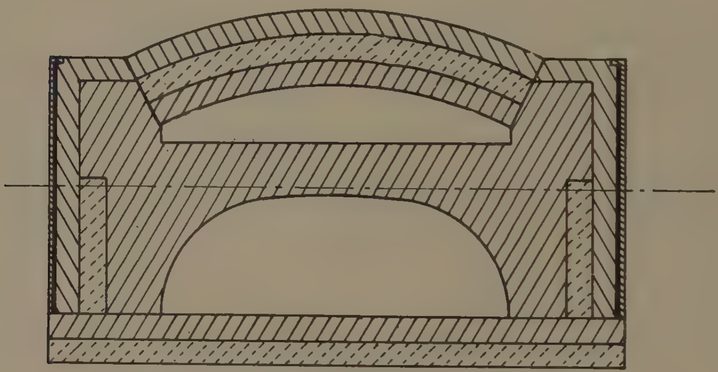


Fig. 13A—Cross section of old process patenting furnace.

tion. The maximum temperature generated within the furnace is obtained at the most desirable position in the furnaces or just before the wire passes out of the furnace into the air. The furnace gases pass over the top of the arch and exit into a flue on the same end of the furnace in which the burner is placed. As the wire travels in the opposite direction to the furnace gases, opportunity is presented for both gradual heating of the wire and utilization of heat in the waste gases.

The same type of furnace is utilized for heating the lead kettle when the double lead patenting process is used. A perforated brick arch is placed in the area marked "B-B" Fig. 13 B on which the lead kettle rests.

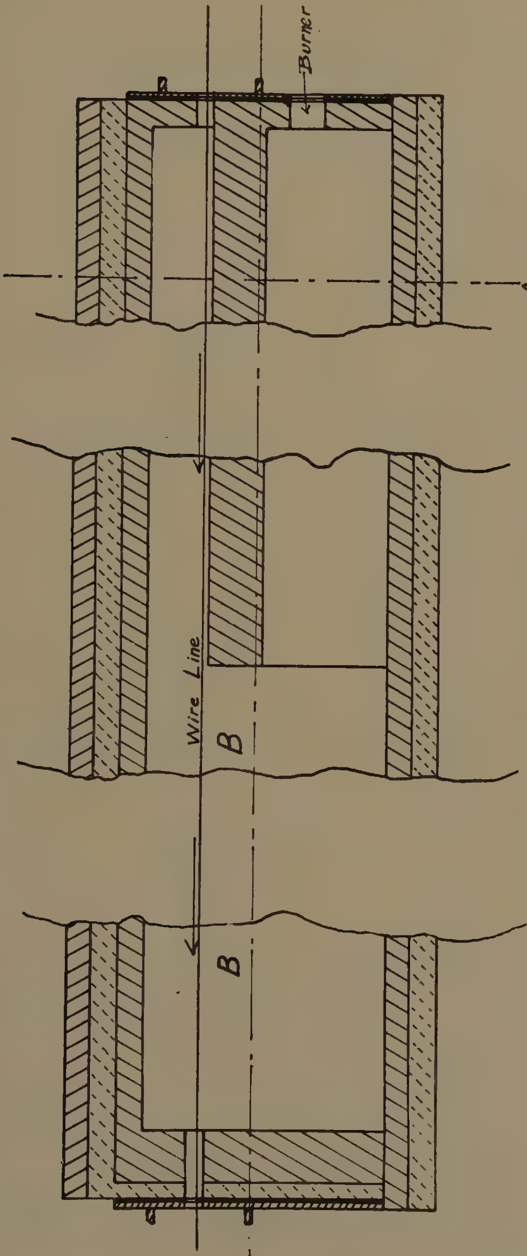


Fig. 13B—Longitudinal section through middle of old process patenting furnace.

The hot gases pass up through the interstices of the arch, entirely surrounding the bottom and sides of the kettle, after which they leave the furnace in the same manner as described above, supplying an opportunity to utilize the waste gases for reheating the wire before it enters the lead kettle. The colder lead bath used with this process obtains the greater proportion of its heat from the hot wire entering it although additional heat may be bypassed from the hot lead kettle furnace, if necessary, to the colder lead kettle.

If the cold lead pan is removed from the end of the furnace and replaced with a trough through which is circulated a supply of quenching oil, then we have an oil-fired continuous hardening equipment. For drawing the temper, a separate oil-fired lead kettle is arranged back of the quenching oil troughs. The same design with lead kettle in place may further be used for the continuous annealing of wire in lead.

Furnaces of this type consume much smaller quantities of fuel per hour as compared with open-hearth furnaces. Burners are, therefore, smaller in all details and the possibilities for clogging of burners due to mechanical impurities in the oils is much greater than experienced where consumptions are quite large as in open-hearth practice. Greater care must, therefore, be exercised in keeping a clean supply of oil flowing at all times.

With large tonnages of wire or rods to be handled, it is desirable to segregate similar heat treating equipment and use several separate oil supply systems rather than attempt too large an individual installation. The arrangements for supplying fuel oil to the various furnaces have been described with this idea in mind.

While fuel oils having a density averaging 15° Bé. require the use of an elaborate system for handling, their cheapness as compared with the lighter oils justifies the installation required for handling them for furnaces of the above type.

Fuel oil is brought to the storage tanks by tank cars where it is unloaded by pumps having strainers in the suction line. It is not customary to pump from storage tanks directly to the burners as intermittent unloading of oil is too likely to cause a general drop of temperature in the storage tank which would interfere with circulation and atomization. Transfer pumps are, therefore, used to pump the fuel oil from the storage tank into the tank in which it is to be used for furnace supply. Steel tanks used for mill supply are usually placed underground in concrete pits as this assists in keeping the oil at the desirable temperature for pumping. As it is necessary to have each tank vented, vents have been surrounded with small circular steam pipes having jet holes several inches apart pointing towards the center for the purpose of smothering the fire in case of ignition. Steam valves for controlling this feature have been placed conveniently at considerable distance from the tanks. Both sets of tanks are equipped with steam coils for heating the oil and all pumps are in duplicate to avoid delays in case of the necessity for repairs.

As straining is of great importance with small oil consumption per burner, strainers are inserted in the suction line of both the transfer and mill supply pumps, in order to afford all the opportunity possible to remove mechanical impurities. Strainers used for this purpose are illustrated in Fig. 14 in which a cylindrical basket made from wire gauze having 25 meshes per inch is used. Each pump has two strainers with suitable valve arrangements in the suction line so that the strainers may be cleaned without interruption to pumping. Both pumps and strainers when located in places subject to severely cold weather are steam jacketed.

The fuel oil is circulated as described for tar or heavy fuel oil at open-hearth plants with the same provision for combining the supply and return oil line together with a steam line. A stand-pipe of the same diameter as the supply line is, however, inserted in the return line

of the system. The stand-pipe acts as a reservoir and also serves to reduce the effects of pump pulsations which are particularly aggravating with small oil consumptions per burner. A valve is placed at the top of the stand-pipe to regulate the amount of oil returned. Oil supplied under a pressure of 35 to 40 pounds per square inch and steam under pressure of 125 pounds per square inch give the most satisfactory operating conditions. Dry steam is not only desirable but essential and steam separators are used in the line where necessary.

The above describes the system used for handling

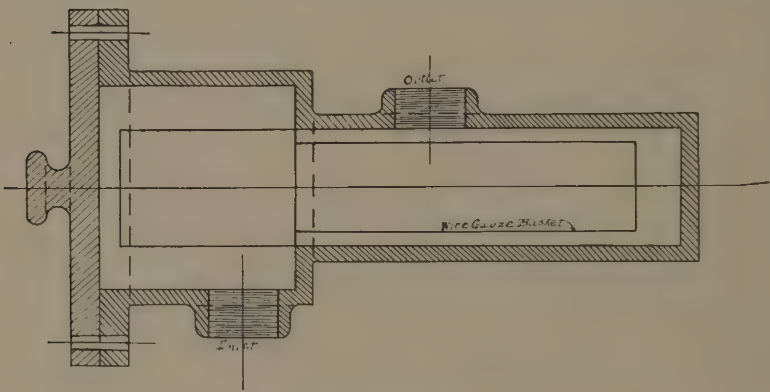


Fig. 14—Oil strainer.

heavy fuel oil for several supply systems, accommodating a fairly large number of furnaces. The lighter fuel oils may be handled with less attention to their temperature. Where small heat treating furnaces are required for use in isolated places, the lighter grades of fuel oil requiring no elaborate methods for handling can be utilized quite favorably by the installation of a small pressure blower and fuel tank, the blower supplying both the air for atomization and pressure for forcing the fuel from the tank to the burner.

Conclusions

Liquid fuels when available at satisfactory prices may be adapted to a large variety of furnaces used in conduct-

ing metallurgical operations. The relatively small initial expenditure required for its application and the ease of manipulation of furnace temperatures make the use of liquid fuels quite attractive. Success in using this type of fuel depends on furnace design, proper methods for its distribution to the furnace, and on burners which will thoroughly atomize the fuel. In the future development of the use of liquid fuel for metallurgical furnaces, there are at least two important principles to consider in an effort to obtain further economy. One of these is the adoption of the principle of mechanical injection now used quite extensively with boilers, and the other, the use of the recuperative principle wherever it can properly be applied in the construction of furnaces which now obtain their air for combustion at atmospheric temperatures.

Vice-President Topping: In discussion of Mr. Helm's paper I will call upon Mr. J. A. Larocca, combustion engineer, The Texas Company, New York.

Discussion by J. A. Larocca

Combustion Engineer, The Texas Company, New York

I have read with much interest the paper by Mr. Helm on the use of liquid fuel in metallurgical furnaces. The open-hearth furnace described, which operates on two grades of fuel oil, is a novel and interesting installation and illustrates a growing and logical tendency towards the heavy and cheap fuel oils in industrial heating operations. It seems to me that in this installation the light oil lines with the objectionable dead-end feature could be dispensed with and the circulating system used for both oils instead of for the heavy oil only. This change in the installation would simplify it and reduce the first cost. To avoid leaving the lines full of heavy oil at the end of the heat, the light oil could

be turned on a short time before the end of the operation.

It has occurred to me that a few remarks on some fuel oil applications not mentioned in Mr. Helm's paper might be of interest.

The importance of low-sulphur fuel oils in high temperature processes in the steel industry is well known. The same restriction as regards sulphur applies to the brass manufacturing industry. The sulphur content is here of considerable importance, especially in furnaces used for annealing or heat-treating sheet brass and copper. In these processes the furnaces are of the underfired type with the burners located below the charging platform. The products of combustion pass up through and around the platform and so come in contact with the metal. It has been found that, if the sulphur content exceeds one-half of one per cent, the metal is noticeably discolored and rendered unmarketable. Additional treating is required to remove the discoloration and, as this is expensive and lowers production, it has become a general practice for brass mills to require that fuel oils for this class of work have a maximum sulphur content of one-half of one per cent. While other heating operations in a brass plant might be performed satisfactorily with cheap high-sulphur oils, the inconvenience and expense involved in handling two grades in the same plant have up to the present time made this practice undesirable.

While fuel oil has been used for many years in industrial heating operations of many kinds, it was not until the discovery of the Mexican oil fields in the early part of this century that cheap fuel oils began to appear in the American market in considerable quantity. The great inherent advantages of oil as fuel and the low cost of Mexican fuel oil in recent years have caused it to displace coal in many boiler plants. Instances arose where large plants operating furnaces with light fuel oils of domestic origin were faced by the desirability of burning in their

boiler plants the cheap Mexican fuel oil instead of coal. A change, however, meant the use of two oils, a heavy oil for the boilers and a light oil for the furnaces, with consequent complication and expense. In many cases the idea of firing the boilers with oil was abandoned on this account, although in some instances light oil was used both for boilers and furnaces. However, as experience with heavy fuel oil increases, there is a growing tendency to use this grade in all operations where the nature of the work permits, so that the lighter oils are gradually being abandoned for many classes of work.

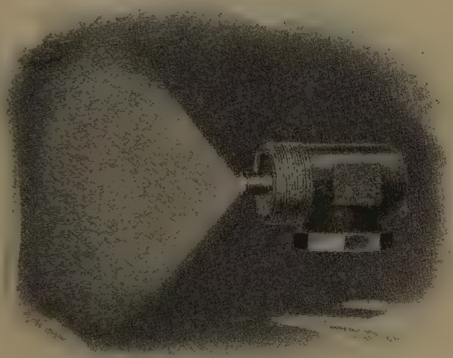


Fig. 1—Anthony Nebulyte Burner, showing spray obtained by forcing oil under moderate pressure through specially designed tip. Air for combustion is admitted through pipe around oil nozzle.

There are plants today which have solved the problem of using one grade of fuel oil for all purposes. Two plants in the vicinity of New York use a cheap heavy oil both for boilers and furnaces. One of these plants manufactures steel products and operates annealing furnaces and heating furnaces for drop forges. The equipment installed meets the best standard practice for handling heavy fuel oil, and consists of storage tanks equipped with heating coils, auxiliary supply tank, strainers, pumps and air chambers, oil heaters, temperature recording devices, oil meters and steam atomizing burners of approved design. All pipe lines are laid in underground trenches with a steam line adjacent to keep the oil warm. The viscosity of the oil is reduced

by preheating in the storage tanks to about 140° F. The oil for the boiler room is pumped from the auxiliary supply tank through the oil heaters and heated to 180° F. before it reaches the burners. The oil for the furnaces is pumped from the auxiliary tank directly to the burners without further heating, and is atomized by compressed air or steam. The air pressure is about 100 lbs. and the steam pressure about 125 lbs.

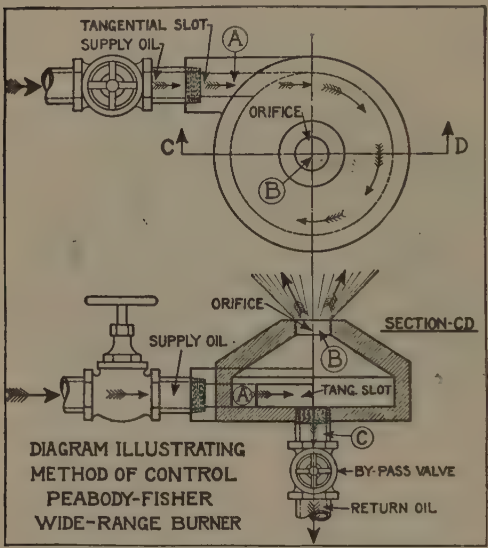


Fig. 2—Peabody-Fisher Wide Range Mechanical Burner.

In the annealing furnaces steam is the atomizing agent, the furnace stack drawing in the necessary additional air for combustion. In the forge heating furnaces compressed air is the atomizing agent. The air jet not only atomizes the oil but also furnishes at the same time a large part of the air needed for combustion. The oil used in this plant is Mexican fuel oil of approximately 14° Bé. gravity, containing about 145,000 B. T. U. per gallon. The sulphur content may run as high as 4¾ per cent, yet it has been found that no noticeable detrimental effects are produced in the product.

The other plant is a large copper refining plant. The furnaces are fired with the same grade of oil as that used by the steel plant, and the same general plan outlined above is followed for handling the oil. Part of

the fuel oil goes to the boiler plant and is preheated to 180° F. in two stages before reaching the burners, and the rest is preheated to about 150° F. and goes to the

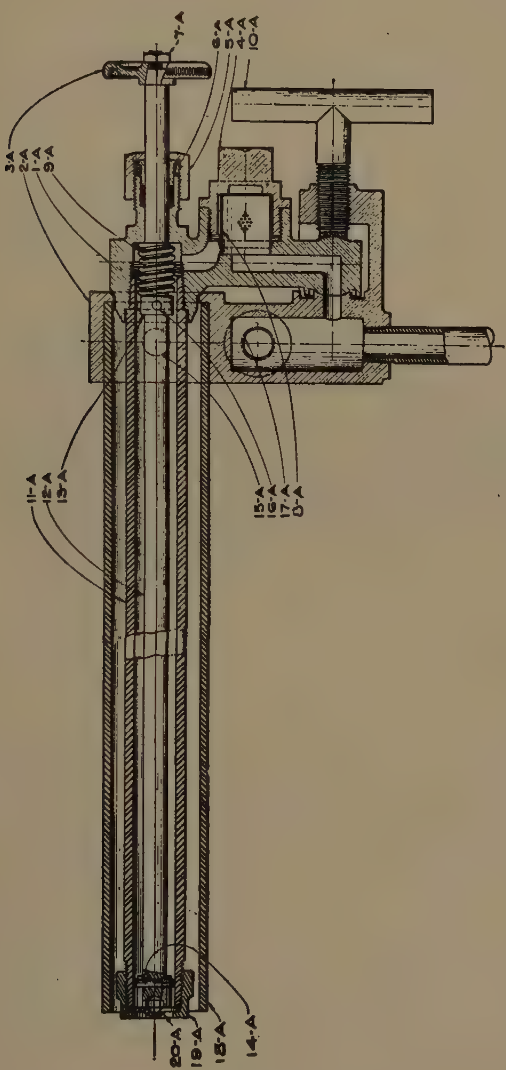


Fig. 3—Coen Adjustable Mechanical Atomizing Burner. 1-A. Burner valve. 2-A. Burner socket. 3-A. Hand wheel. 4-A. Strainer nut. 8-A. Strainer. 9-A. Tension spring. 10-A. Socket clamp. 11-A. Burner tube. 12-A. Adjusting rod. 13-A. Adjusting rod collar. 14-A. Regulating pin. 18-A. Guide pipe. 19-A. Tip clamp nut. 20-A. Burner tip.

furnaces. Steam atomizing burners are used both on the boilers and on the furnaces. No detrimental effect on the copper appears to be produced by the sulphur

in the oil, and while it is admitted by the management that a lower sulphur content would be more desirable, the greater economy of the grade now used more than offsets the undesirable sulphur feature.

These plants represent large installations, the consumption of oil averaging several million gallons a year. They have successfully avoided the use of two grades of oil and have reduced expense and complication of equipment.

It appears to me that many heating operations, which are now performed by burning the light and more expen-

Fig. 4—Todd Mechanical Oil Burner. 1. Tip. 2. Nut. 3. Body. 4. Strainer and atomizer. 5. Tube. 6. Handle. 7. Union bushing. 8. Housing. 9. Housing Screw. 10 Jacket tube.

sive fuel oils, might be performed just as satisfactorily and more economically with the cheap high-sulphur oils, using equipment properly designed for the purpose. The success attained by these two plants should induce other users to investigate the possibilities of cheap high-sulphur oils.

The statement in Mr. Helm's paper regarding the application of the mechanical burner to metallurgical furnaces is timely. The oil burners now used for such furnaces invariably utilize either steam or air under pressure as the atomizing agent. The use of these agents involves considerable expense and special equipment. The elimination of this type of burner and the substitu-

tion for it of the mechanical type would be a considerable step forward in the economic application of fuel oil to industrial heating operations.

As is well known, in the mechanical type of burner, oil, preheated to a temperature of 200° to 250° F., is forced at high pressure through the burner. Before it reaches the orifice, it passes tangentially into a central

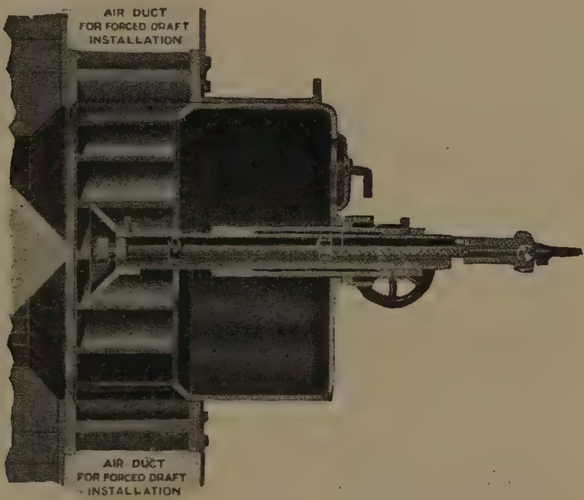


Fig. 5—Dahl Mechanical Atomizing Burner, consisting of tip of special design mounted on end of burner pipe, which extends into furnace front through an adjusting pipe. On the end of adjusting pipe is a cast iron deflector which can be adjusted by moving in or out to position where flame will receive proper amount of air for perfect combustion. Operator can regulate supply of air to burner by adjusting area of air inlet. This is accomplished by means of a rack and pinion attachment fitted with hand wheel, which operates a movable part of the furnace front to open or close the air inlet.

chamber where it attains a rapid whirling motion. On leaving the orifice a powerful centrifugal action is therefore set up which disrupts the oil stream into minute particles. The atomized oil is thrown away from the axis of the burner and distributes itself along a thin conical surface with the apex at the orifice and exposed on all sides to the air.

The principle involved is admirable for atomizing oil of any viscosity without the use of either steam or air,

The conical shape of the flame makes it satisfactory for boiler practice and for some types of metallurgical furnaces. To adapt the mechanical burner to furnaces such as the open-hearth furnace where comparatively long and broad flames are necessary, the shape and length of the flame produced by the mechanical burner must be altered. This might be accomplished by modifying the whirling motion, by combining jets, altering the jet velocity or by changing the shape of the orifice. The field is a new one for investigation and is limited only by the inventiveness of the experimenter.

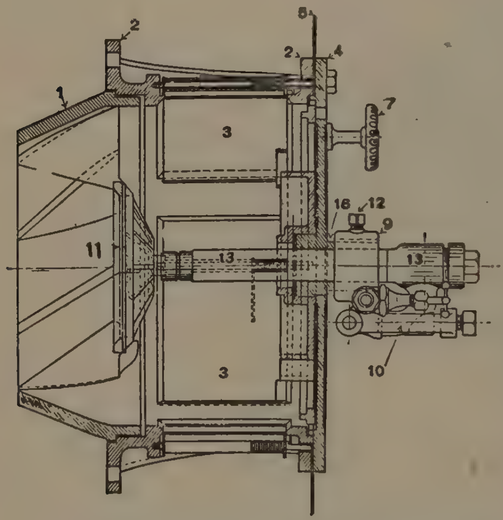


Fig. 6—Babcock & Wilcox Mechanical Atomizing Burner. 1. Conical casting. 2. Register casting. 3. Automatic doors for controlling air supply. 4. Cover plates. 5. Radiator guard. 7. Handle for rotating air doors. 11. Conical shaped impeller plate for regulating distribution of air at burner nozzle. 13. Mechanical atomizer.

In adapting the mechanical burner for metallurgical work provision should be made for protecting it against the high temperatures prevalent in certain processes. Not only should the burner be protected against the destructive action of heat, but undue heating of the burner should be prevented, as carbonization of the oil would undoubtedly occur and would clog the small passages in the tip. Various methods for protecting oil burners against heat have been described by Mr. Helm. Some of these methods may also prove suitable for the mechanical burner.

The principle of preheating has been found of great

assistance in oil burning. Hot oils atomize easily and burn more completely. Preheating is also of advantage when applied to the air for combustion. The principle of preheating air is rarely applied in boiler practice and only in some cases in metallurgical furnaces. Considering the vast amount of heat that is lost during heating operations, it would seem that the problem of reclaiming some of this waste heat by preheating the air for combustion, and so increasing the present low efficiency of heating furnaces, should not prove too difficult to solve.

In conclusion I might say that the adaptation of the mechanical burner to industrial heating processes and the broader use of the principle of preheating appear to be the next important steps in the economic application of oil burning.

VICE-PRESIDENT TOPPING: The next paper is The Thermal Efficiency and Heat Balance of an Open-hearth Furnace, by C. L. Kinney, Jr., superintendent, No. 1 Open-Hearth Department, South Chicago Works, Illinois Steel Company, South Chicago, Illinois, and Mr. G. R. McDermott, assistant chief engineer, South Chicago Works, Illinois Steel Company, South Chicago, Illinois. The paper will be presented by Mr. McDermott.

THE THERMAL EFFICIENCY AND HEAT BALANCE OF AN OPEN-HEARTH FURNACE

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AND

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Before disclosing the subject matter of this paper, and in view of the economic significance of the subject involved, the authors desire to present the following facts and suggestions for consideration by the members of the Institute.

The independent investigator of open-hearth furnace efficiency, in planning such work, is immediately confronted by the question of, not only what shall be observed and recorded, and of methods and interpretation of such observations, but also by questions of correctness of the values used in the calculations.

He also has to determine a scheme of tabulation of the data obtained, in such a form that the conclusion drawn shall make an emphatic appeal to those in charge of open-hearth plants and thus excite a larger interest in this important matter.

Considering the magnitude of the industry, there exist but few complete investigations of the subject, and practically all those published differ widely both in final form and in the thermo-chemical and thermo-physical values used. It seems obvious to us that there exists a very great and important need that all work of this character should be carried on by standardized methods, values, and forms, which would make comparisons of

results possible. It also seems evident to us that the adoption of such a code would do much toward awakening a greater interest in this matter, which would certainly be reflected by pronounced economies in the industry. We therefore suggest that, representing, as it does, the iron and steel industry of this country, it lies specifically within the jurisdiction of the Iron and Steel Institute to appoint a committee to prepare and sanction some such standard method of determining the thermal efficiency and heat balance of the open-hearth furnace, and we further suggest that those members, who manage such plants, pledge themselves to use in such investigations the standard method authorized by the committee. It is distinctly without our province to make specific recommendations concerning this code, but we feel that the method used by Mr. Fred Clements in his excellent paper on this subject, which appears in the Journal of the Iron and Steel Institute (London), 1922, Vol. CV, p. 429, is the most simple and practical of any extant, and for this reason we have in our presentation very largely followed his plan.

The purpose of this particular investigation was to determine the present efficiency and heat balance of a typical open-hearth furnace as operated at these works and to show what improvements have been made and wherein the losses shown may be minimized. With this in mind we show a design of a 100-ton furnace in which are embodied certain improvements revealed in the following text.

Regenerators

The 100-ton furnace (see Fig. 3), as will be noted, has been provided with insulated checker chamber walls only, but no increase of combustion chamber efficiency has been assumed. While it is unquestionably true that an increase in checker chamber temperatures is followed by increased combustion temperatures in the melting chamber, we do not feel warranted with the data

available in making a specific increase in melting chamber efficiency, but are satisfied to show that the heat conserved by this insulation is of advantage in our waste heat boiler only. It may be asked why the checker chamber roofs are not so insulated, thus further conserving heat. To this question we will reply by saying that the peak temperature in these chambers is at present not far below the softening temperature of fire-brick and it is felt that any great increase would involve chamber roof collapse.

In an open-hearth furnace the two main features which make its operation possible are the regenerative chambers and a port arrangement, capable of producing a high temperature flame within the melting chamber.

The fundamental principles involved in regeneration of heat, by means of checker work, have been so many times stated, that a repetition of them is not considered necessary. It unfortunately is true that too many open-hearth furnaces are operating with checker work which in part only uses these basic theories, and in consequence their efficiency is low.

It should be borne in mind in designing checker work and chambers that to merely remove from the outgoing gases a very large proportion of their sensible heat does not mean high efficiency in the melting chamber, because the production of a high temperature fuel column is in part a function of high temperature incoming air and gas, and such temperatures cannot be reached if the sensible heat of the waste gases is dispersed over too great an area. From this it is obvious that the most efficient checker must have in its upper section the maximum concentration or intensity of heat that will permit incoming gas and air to reach the ports at the highest possible temperature and at the same time in the bottom section to discharge the waste gases at a low temperature. A strict application of the foregoing principle would of necessity lead one to design a deep checker chamber of small horizontal cross section and

the checker work itself with very small flues; for it is also a fundamental principle in heat transfer of this nature that the highest efficiency is obtained the more nearly we can approach the critical velocity of the gas used.

The commercial as opposed to the purely technical aspects of the deep checker work and small flue are as follows: the deep chamber involves an increase in charging floor height, if ground water is to be avoided, which adds to building cost and in addition consumes, in the form of energy necessary to put up on the charging floor the raw material for steel making, probably more fuel than is saved; nor can there be any question of the added labor cost involved in the removal and replacement of such checker work. The very small flue area is objectionable from a practical standpoint, because in its upper sections it rapidly becomes clogged with oxides, and thus the efficient campaign of a furnace is reduced to an uneconomical extent. One is thus forced in the practical design of checker chamber and checker work to sacrifice a certain amount of theoretical efficiency, which is more than compensated for in the form of practical gain. The checker work shown in our drawing of the 1922 and 100-ton furnaces was designed to give the greatest possible inlet area (number of top openings per square foot of horizontal area) and the maximum square feet of exposed surface per cubic foot of checker brick, but also, in its individual flue area of thirty-six (36) square inches, gives a velocity high enough for a very excellent rate of heat transfer without premature clogging and consequent suspension of efficient operation. Thus, based upon local conditions and results obtained over an eight-year period, we feel that this practical compromise with theoretical considerations represents for us the best available type, and so have used it in the 100-ton furnace. Specifically the net gain in efficiency represented by this checker work and expressed in actual pounds of coal per ton of ingots is as

follows. Period of 1912, with checkers shown in Fig. 1 and burning Universal mine run coal, which has an average proximate analysis as follows: volatile, 35 per cent; fixed carbon, 45 per cent; ash, 8 per cent; moisture, 12 per cent; B. T. U., 11,445, the average coal per ton of ingots produced was 750 pounds, and over an equally long period during 1914, using the improved checker work and the same coal, the pounds per ton of ingots was reduced to 684, a decrease of 8.8 per cent. Had we been using, during the periods named, what may be termed a standard gas producer coal of high fixed carbon, low ash and moisture content, having a heat value of 13,400 B. T. U., our coal per ton of ingots would have been for the 1912 period, 600 pounds and for the 1914 period, 548 pounds, this last figure representing actual results. It should be unnecessary to mention the desirability of the proper arrangement and size of flues under the checker work, and in the design shown we have attempted to minimize short-circuiting by progressive increase in area from bridge-wall to valve flue, at the same time keeping ample area in all parts in order to take care of deposited oxides. Ample insulated flue area, between regenerative chamber and valves and boiler, has also been provided.

Gas and Air Ports

The area of gas port, or ports, is determined by the proper velocity of gas used. This area varies with the character of the gas; a low B. T. U. gas having a high hydrogen and water vapor content and consequently a larger volume per unit of heat, naturally requires more area than a gas made from a better coal.

The air port area is in proportion to the theoretical air necessary to burn the gas plus a certain minimum excess. The location of the bottom of the gas port should be high enough to prevent partially unburned gas from coming in immediate contact with the bath, thereby delaying combustion. It should be noted in this connec-

tion that the modern furnace by providing a combustion space for the incoming gas is in marked contrast in this respect (delayed combustion) to some older types. Yet today it is not unusual to find furnaces, the face of whose gas ports are too far advanced into the melting chamber and the bottoms of the ports not high enough above the bath level. Inspection of an empty bottom, where such an arrangement of gas port is used, reveals the end banks extending an abnormal distance into the crucible (bath space). The antithesis of such a condition prevails where gas ports are set too far back, thus causing a very high temperature flame to play upon and pass over the end banks. With this condition these banks will soften and cut instead of building out and trouble will be encountered in the form of delays in repairing them, and in the loss of heats.

The correct proportioning of gas and air ports and their relative locations, etc., are based, fundamentally, upon a desire to obtain the most intimate mixture of the two gases as quickly as possible. However, the problem is further complicated by the necessity of directing the intensely hot flame thus produced so that in its relation to bath surface, it shall give up heat mainly by conduction and at the same time be kept away from the side walls and roof of the melting chamber. In the later type of furnace, the gas ports have been so placed that the so-called flame temperature of the stream of entering gas is not reduced by immediate contact with the bath to a point which inhibits an efficient further flame propagation. Having thus provided a hotter fuel column, it follows that provision must be made for its proper direction. Mere increase in velocity at or adjacent to the point of preliminary combustion is inadequate and it is thus necessary to resort to a reduction of area well in advance of this zone to prevent velocity dispersion and an uncontrollable fuel column. Reference to Fig. 1 Port End will show that in this early type of furnace, while a preliminary combustion zone existed, there was

a decided lack of contact area between incoming gas and air. A cross section of the combustion chamber at the gas port mouth shows that only the upper portion of the producer gas column is in contact with the air column. Fig. 2 shows how this area of contact has been increased by the admission of air on the sides of the gas port. Fig. 3, showing the 100-ton furnace, exhibits another arrangement in this respect, in that the fuel column is divided and by means of the damper the air is forced into a still more intimate contact.

Referring again to Fig. 1, it will be noted that, after leaving the zone referred to in the preceding paragraph, the area of greatest confinement was 43 square feet, and the continuity of direction and compactness of the fuel column was largely a matter of velocities and confinement in the zone immediately adjacent to the gas port mouth. Any attempt to increase fuel and air contact areas by adopting the plan of preliminary combustion, while maintaining 43 square feet as the area of greatest confinement, would have been followed, perhaps by better flame propagation, but certainly by a high temperature fuel column, which lacking direction, would have unquestionably destroyed the roof and side walls in the course of a short campaign.

To maintain the proper direction and compactness of the fuel column under the 1922 condition of preliminary combustion, it was necessary to prevent velocity dispersion, by decreasing the area of confinement to 20 square feet, which is practically the amount indicated by the increased volume of the gases, due to their temperature increase between the face of the entering port and the point of greatest confinement. Not only does this decrease in area (23 square feet) result in a regular compact fuel column, but by increasing the intimacy of the mixture of gas and air an improvement in combustion is attained. Such reduction in area does not, as might be supposed, affect the efficient removal of the products of combustion from the melting chamber.

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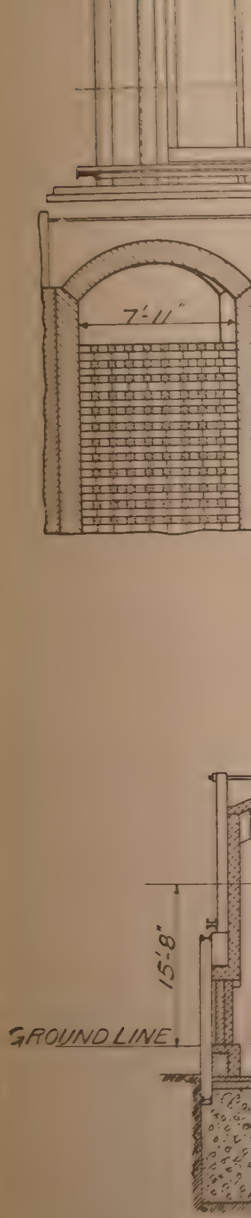

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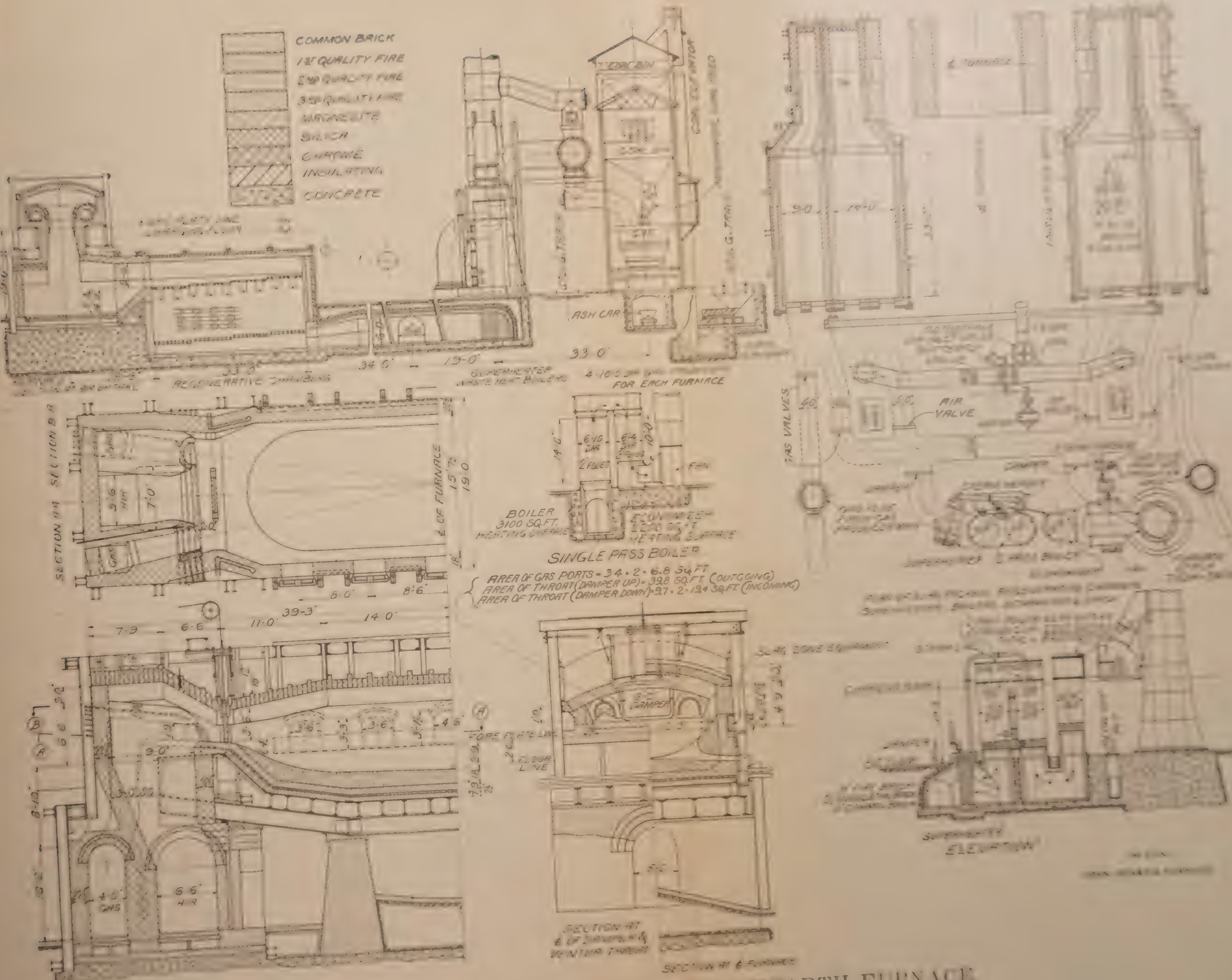

FIG. 3—PLANS FOR A 100-TON OPEN-HEARTH FURNACE.

With a furnace of this type, there exists, however, a limit in the input energy in the form of gas, lower it is true than in the 1912 type, but by no means the ultimate. In all probability this limit is a function of the amount of air capable of being delivered to the melting chamber by the stack effect of uptakes and checkers, against the melting chamber pressure. The ideal furnace must retain those features which promote partial and complete combustion, compactness and direction of the fuel column, but should in addition make possible a greater energy input per unit of time, which by speeding up the process reduces heavy radiation losses per unit of fuel fired.

The 100-ton furnace not only increases intimacy of mixture for the necessary combustion, and the confinement of area necessary for efficient control of the flame, but in addition provides an outlet area capable of handling a greater input energy.

Slag Pockets

Size should be such that the furnace campaign will not be shortened by premature filling. This rate of filling varies with the completeness of the combustion of fuel, character of charge, degree of permissible water-cooling and refractoriness of the brick. Air-cooling of division walls minimizes gas leakage. Air-cooling of wall between slag pocket and checker chamber reduces the danger of slag breaking through and clogging checkers and flues. Air-cooling of the bottom produces a physical change in the deposited slag which facilitates its removal.

The 100-ton furnace shows the air-cooling system connected to a fan which supplies air to the furnace. This arrangement increases circulation and renders cooling more efficient and adds sensible heat to the incoming air.

The 100-ton furnace shows a substitution of the damper type valve for the rotating water-cooled type

and while there is no question of the superiority of the former due to its easier flow lines, there is also much less heat loss in the cooling-water and the absence of water vapor carried into the furnace from the exposed water of the seal. It is also thought unadvisable to attempt to show a specific increase in combustion chamber efficiency from such an improvement. It should be emphasized, however, that a valve of this type, used on the air flues, eliminates the short-circuiting of a larger or smaller portion of the incoming air to the stack flue, which in the butterfly type comes from faulty sealing of the valve tongue and entails losses more serious than commonly supposed.

Water Cooling

The amount of useful energy which is absorbed from the furnace system by water-cooling devices has been and is a subject of polemic rather than practical discussion. In making a decision whether or not to water-cool, both commercial advantages and thermal loss should be carefully weighed, the one against the other. Consider, for example, the water-cooling of a gas port. It is granted without discussion that the highest possible temperature in the burning fuel column is a function of the temperature of the incoming gas and air, and that any absorption of heat will be followed by a diminished flame temperature and a consequent loss of efficiency. There is, however, another factor of prime importance in efficient open-hearth furnace operation, which has been mentioned in that section of the paper dealing with port construction, namely, flame control and direction, and its importance to heat transfer to the bath and the maintenance of brick-work. It seems obvious to us, while a dry port will produce a slightly higher flame temperature over a short life, that the time lost in repairs and the inefficiency of and damage done by a poorly controlled flame, before repairs are made, actually produces a far greater commercial loss than

the slight reduction in flame temperature from a *proper* amount of water-cooling. Considerations of this character based on experience, have led us to adopt the cooling devices shown in the 1922 and the 100-ton furnace.

Waste Heat Boiler

The waste gases from metallurgical furnaces, particularly those issuing from the open-hearth, present an excellent opportunity for utilization in steam generation by means of a waste heat boiler.

The first studies and installation of a waste heat boiler in connection with an open-hearth furnace were made at the Illinois Steel Company, South Chicago, during the year 1910 and upon the results then obtained have been based the rapid development and applications of the modern waste heat boiler.

The sensible heat in the gases after passing through the regenerators of an open-hearth furnace represent 30 to 50 per cent of the heat available in the fuel as fired.

The absorption of the heat content of these gases is largely obtained by convection which necessitates the travel of the gases at high velocity over the heating surface of the boiler. Consideration of the formula governing this phenomenon will develop the reason.

The rate of heat transfer for either fire-tube or water-tube boilers may be expressed in the formula:

$$R = \frac{H}{T-t} = a + b\frac{W}{A}$$

R = heat transfer rate in B. T. U. per hour per square foot of heating surface per degree F. difference in temperature.

H = B. T. U. transferred per hour per square foot

a and b = constants.

$\frac{W}{A}$ = Mass velocity expressed as pounds of gas per hour per square foot of area of gas passage.

In order to absorb heat by convection, the molecules of the flowing gases come in contact with the heating surface of the boiler and impart their heat to it. The rate at which the heat is imparted to a unit surface

depends, therefore, on the number of gas molecules coming in contact with it per unit of time.

By referring to the above equation of "R" for different tube diameters, it will be noted that the value of "R" not only increases with the reduction in diameter of the flue, but also with an increase in the ratio of $\frac{W}{A}$, mass velocity. This absorption phenomenon manifests itself to a greater degree when the gases are at or above their critical velocity.

The above phenomenon and advantages also apply to economizers. During the past year, three fire-tube type of waste heat boilers, equipped with fire-tube economizers, were installed in connection with open-hearth furnaces, and the results obtained from both boilers and economizers further confirmed the theory outlined above.

By referring to Fig. 3 it will be noted that a fire-tube type of boiler and economizer is shown, of sufficient size to handle the waste gases leaving a 100-ton furnace. Both the boiler and economizer are constructed with 3-inch diameter flues.

The reduction of space required, lower first cost, less draft loss, elimination of air leakage due to infiltration, and ease of maintaining a clean surface on the gas side of the heating surface for equal evaporation led to the adoption and installation of the fire-tube type of waste heat boiler at South Chicago in 1915, 1917 and 1921.

In order to illustrate, by comparison, what may be accomplished for equal output by a boiler constructed with 2-inch diameter flues as a means of reducing the first cost and space requirements, a separate outline is shown on the same sheet of such a boiler and economizer. It is the belief of the authors that no difficulty will be encountered by the use of the 2-inch flues due to accumulation of dust in them. The relatively high velocity of the gases through the flues will tend to keep them clean; dust accumulation to any extent will be at the

entrance of the flues on the bottom of the boiler. This dust can be readily removed periodically as the occasion arises.

The square feet of heating surface of the boiler and economizer constructed with 3-inch flues is 6250 and 2200 square feet respectively, while the square feet of heating surface of the boiler constructed with 2-inch flues and an economizer having 3-inch flues is 3100 and 2200 respectively. The latter installation would consume more fan power on account of the greater friction loss through the 2-inch flues as compared with the 3-inch flue. The cost of this power would be offset by the difference in first cost of the installation and interest on the investment.

Attention is called to the table compiled and shown in Fig. 7 which gives the "Overall Thermal Efficiency of the Utilization of the Coal Burned" in operating an open-hearth furnace with and without a waste heat boiler. The furnace equipped with a waste heat boiler utilizes as useful work 35.9 per cent of the energy in the coal fired at the producers, as compared to 16.1 per cent with the furnace not so equipped. This difference would be further increased by the installation of an economizer.

Gas House

A modern gas producer plant has been shown, in which are provided mechanical producers, large insulated gas mains and a covered coal storage. Four 10-foot mechanical gas producers are provided, with top poking and leveling apparatus, bottom agitation, ash removal and disposal. The peak gasification thus provided for using a mine run coal of the following natural proximate analysis (volatile, 35 per cent; fixed carbon, 44 per cent; ash, 8 per cent; moisture, 13 per cent), is approximately 27 pounds per square foot of effective grate area per hour, which is well within the limits of efficient continu-

ous operation of a modern producer. It is true, that if a better grade of coal were used the capacity provided is excessive, yet if consideration be given to the gradually decreasing quality of gas coals and the irregularity of the coal mining industry, it was felt justifiable to provide an ample margin of safety in gasification rates. The enclosing of the coal storage bin is shown and recommended on the basis of thermal losses arising from excess extraneous water in the fuel.

Thermal Efficiency and Heat Balance Test

In order to collect and observe the required data to confirm the soundness of the before outlined theories pertaining to regeneration and combustion, it was necessary to determine the thermal efficiency of a furnace designed along the lines of these theories and compare by the same method the performance of a furnace not embodying the principles as outlined. In addition to the determination of the thermal efficiency a "heat balance" was made to show the distribution of the thermal energy, from which further changes may be made leading to greater economies.

To collect the basic data, observations were made on three successive heats on Furnace No. 24 at Open-Hearth No. 2, South Works, Illinois Steel Company, which we considered was approximately at a point in its campaign representative of normal furnace conditions. On account of the necessity of calibrating the instruments and coordinating the efforts of the personnel engaged in observing and recording the required information, the results of the observations taken on the first two heats were considered only as preparatory work.

During the test a detailed log was kept of the furnace charge and operation. The weight of the coal fired in the five gas producers was accurately weighed and sampled. Both incoming charge and the product, in which were included ingot butts and scrap on the pit side and all slag, were carefully weighed and sampled. The furnace

FIG. 4—LOG OF HEAT No. 24565, SEPTEMBER 26, 1922—OPEN-HEARTH No. 2, SOUTH WORKS, ILLINOIS STEEL CO.

Time	Operation	Material Charged	Weight Lbs.	C	Si	Sul.	P	Mn	Fe	SiO_2	FeO	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	Sul.	P_2O_5	Fe	Temp. of Slag and Metal by Optical Pyrometer	Air Meter Reading in Inches	Air Meter Volume	Port of Entry Gas and Air
3.45 P.M.	Tapped Heat No 24564.																						
3.50	Gas off.																						
[illegible]	Making Bottom.						.004			.32			1.49		48.58	32.58	.126		.38				
4.10	Finished Bottom and Front.																						
4.10	Gas on Left End.																						L.H.
4.10	Began Charging Lime.	Limestone	12000				.006			.34			.30		54.60	.88	.042		.20				
4.15	" " Ore.	Ore	19800				.050	.13		9.29	1.18	72.44	1.10		1.60	2.84			51.76				
4.15	Gas on Left End.																						
4.30	Began Charging Scrap.	Steel Scrap	70000	.20	Tr.	.040	.015	.40													.040	5574	
[illegible]	Gas on Left End.																						
4.40	Finished Charging Scrap.			.20	Tr.	.040	.015	.40															
[illegible]	Gas on Right End.																						R.H.
4.47	Doors Banked.																				.033	5060	
5.00	Gas on Left End.																						L.H.
[illegible]	" " Right "																				.040	5574	R.H.
[illegible]	" " Left " Gas Poor.																				.033	5060	L.H.
[illegible]	" " Right "																				.041	5620	R.H.
[illegible]	" " Left "																				.033	5060	L.H.
[illegible]	" " Right "																				.041	5620	R.H.
6.30	" " Left "																				.031	4920	L.H.
6.45	" " Right " Gas Good.																				.039	5505	R.H.
7.00	" " Left "																				.030	4835	L.H.
7.15	" " Right "																				.0385	5472	R.H.
7.30	" " Left "																				.029	4750	L.H.
7.45	" " Right "																				.0405	5605	R.H.
7.46	Hot Metal - 1st Ladle.	Hot Metal	54000	4.30	.95	.032	.220	.41													.026	4500	
8.00	Gas on Left End.																						L.H.
[illegible]	" " Right "																				.038	3485	R.H.
[illegible]	Hot Metal - 2nd Ladle.	Hot Metal	56000	4.30	.95	.032	.220	.41													.026	4500	
8.30	Gas on Left End.																						L.H.
8.35	Monell Slag Test.									21.45	23.16	3.47	2.29	11.93	25.20	9.32	.14	2.43	20.44		.036	5295	
8.45	Gas on Right End.																						R.H.
9.00	" " Left "																				.028	4670	L.H.
9.02	Monell Slag Stopped Running.																				.038	5435	
9.15	Gas on Right End.																						R.H.
9.30	" " Left "																				.028	4670	L.H.
9.45	" " Right "																				.034	5145	R.H.
10.00	" " Left "																				.028	4670	L.H.
10.15	" " Right "																				.035	5210	R.H.
10.30	" " Left "																				.025	4410	L.H.
10.35	Heavy Reaction.																						
10.40	Working on Lime.			.85	.003	.043	.018	.14		22.95	14.15	2.87	2.36	10.33	35.14	9.28	.09	2.79			.037	5300	
10.45	Gas on Right End.																						R.H.
11.00	" " Left End.																				.031	4910	L.H.
11.15	" " Right "																				.037	5360	R.H.
11.16	Addition of Spar.	Spar	150							1.12					2.50	3.8	.004				.0305	4870	
11.30	Gas on Left End.																						L.H.
[illegible]	Addition of Spar.	Spar	200							1.12					2.50	3.8	.004						
[illegible]	" "	"	250							1.12					2.50	3.8	.004				.040	5574	
[illegible]	Gas on Right End.																						R.H.
11.46	Test Taken.			.31	.005	.038	.006	.18		16.39	13.95	3.43	2.13	6.71	46.56	7.30	.14	2.34					
11.51	Slag Heavy.																				.030	4830	
12.00 M.	Gas on Left End.																						L.H.
12.02 P.M.	Addition of Spar.	Spar	150							1.12					2.50	3.8	.004						
12.13	Tests Taken			.13	.004	.033	.007	.17		15.50	13.95	5.36	2.02	6.35	46.75	7.50	.22	2.04			.038	5435	
12.15	Gas on Right End.																						R.H.
12.27	Extra Metal Added.	Hot Metal	4000	4.30	.95	.032	.220	.41													.030	4830	
12.30	Gas on Left End.																						L.H.
12.31	Addition of Spar.	Spar	150							1.12					2.50	3.8	.004			Slag =			
12.33	Good Slag.																			3150°	.037	5360	
12.41	Heat Started in Ladle.																						
12.43	Tests Taken.			.12	.002	.030	.008	.20		15.25	14.14	4.61	1.95	6.19	47.20	8.09	.18	2.04	14.22	Steel =			
12.50	Heat Finished-Bottom Clean																			3050°			

Air Meter Readings. Reading × 27860 = Vol. per Min at 62° F.

Average Temperatures.

Time	L.H. Regenerators Gas Top Regen.	L.H. Gas Top Recup.	L.H. Gas Bottom Regen.	L.H. Gas Bottom Recup.	L.H. Air Top Regen.	L.H. Air Top Recup.	L.H. Air Bottom Regen.	L.H. Air Bottom Recup.	R.H. Regenerators Gas Top Regen.	R.H. Gas Top Recup.	R.H. Gas Bottom Regen.	R.H. Gas Bottom Recup.	R.H. Air Top Regen.	R.H. Air Top Recup.	R.H. Air Bottom Regen.	R.H. Air Bottom Recup.
4.40	1730		[illegible]		2187		460			[illegible]		[illegible]		[illegible]		[illegible]
4.47		[illegible]		1285		2191		1275	1745		[illegible]		[illegible]		[illegible]	
[illegible]	1730		[illegible]		2128		510			[illegible]		[illegible]		[illegible]		[illegible]
[illegible]		[illegible]		1275		2198		1300	1763		1062		[illegible]		[illegible]	
[illegible]	1730		[illegible]		2127		560			[illegible]		[illegible]		[illegible]		[illegible]
[illegible]		[illegible]		1275		2274		1300	1740		[illegible]		[illegible]		[illegible]	
[illegible]	1730		[illegible]		2158		560			[illegible]		[illegible]		[illegible]		[illegible]
6.30		[illegible]		1255		2336		1275	[illegible]		[illegible]		[illegible]		[illegible]	
6.45	1805		[illegible]		2257		560			2175		1215		[illegible]		[illegible]
7.00		2455		1245		2418		1275	1746		[illegible]		[illegible]		[illegible]	
7.15	1830		[illegible]		2208		510			[illegible]		[illegible]		[illegible]		[illegible]
7.30		[illegible]		1215		2445		1250	1838		[illegible]		[illegible]		[illegible]	
7.45	1830		[illegible]		2300		510			[illegible]		[illegible]		[illegible]		[illegible]
7.46		[illegible]		1235		2501		1300	1777		[illegible]		[illegible]		[illegible]	
[illegible]	1805		[illegible]		2328		560			2222		1260		[illegible]		[illegible]
[illegible]		[illegible]		1225		2540		1400	1815		1137		[illegible]		[illegible]	
8.35	1830		[illegible]		2334		510			2273		1260		[illegible]		[illegible]
9.00		2335		1225		2534		1300	1823		1137		[illegible]		[illegible]	
9.02	1830		1116		2392		510			2435		1260		2540		1275
9.30		2330		1225		2548		1300	1753		1137		2342		775	
9.45	1830		1126		2348		535			2315		1260		2553		1350
10.00		2380		1235		2545		1350	1748		1137		2302		780	
10.15	1780		1136		2360		560			2335		1240		2557		1400
10.30		2330		1235		2566		1350			1147		2350		835	
10.40	1830		1116		2353		560					1240		2555		1350
11.00		2230		1235		2585		1350			1137		2334		680	
11.15	1805		1126		2382		610					1240		2622		1300
11.16		2230		1235		2605		1325			1157		2307		740	
[illegible]	1730		1126		2390		655					1230		2563		1250
11.51		2280		1225		2595		1350			1137		2371		760	
12.13	1780		1096		2402		610					1220		2567		1325
12.27		2230		1215		2613		1350			1137		2374		770	
12.43	1790		1096		2400		610					1180		2535		1275

Pyrometer Broke. Couple Broke.

Aver. Temp. (8.30): 1260, 1400, 102

Gas Analyses

Charging. Melting. Working.

STEEL.

	Weight-Lbs.	C.	Si.	Sul.	P.	Mn.
Ingots and Scrap.	177,300					
Ladle Analysis.		.17		.034	.008	.45
Tapping Analysis.		.12	.002	.030	.008	.20

SLAG.

	Weight Lbs.	SiO_2	FeO	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	S	P_2O_5	Fe.
Run Off.	10000	21.45	23.16	3.47	2.29	11.93	25.20	9.32	.14	2.43	20.44
Tapping.	16100	15.25	14.14	4.61	1.95	6.19	47.20	8.09	.18	2.04	14.22

COAL. WEIGHT BURNED = 46,400 LBS.

	Volatile	Fixed Carbon	Moist.	B.T.U.	C	H_2	N_2	Ash.	Sul.	O_2	Combustible Matter
Proximate Analysis.	35.35	44.50	12.55					7.60	1.54		
Ultimate Analysis.					70.95	5.25	1.37	8.65	1.76	12.02	
Calorific Value.				11445							
Ash. (Producer)											11.40

CHEMICAL BALANCE SHEET.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MATERIAL	WEIGHT IN POUNDS	% C	LBS C	LBS CO	% Si	LBS Si	% SiO_2	LBS SiO_2	% P	LBS P	LBS P_2O_5	% Mn	LBS Mn	% S	LBS S
BESSEMER HOT IRON.	1300	3.8	49		1.62	21		45	.073	1	2	[illegible]	8	.034	
BASIC " "	105549	4.2	4433		1.15	1214		2598	.265	280	641	[illegible]	1058	.048	48
" COLD "	8960	4.2	376		1.15	103		220	.265	24	55	[illegible]	75	.045	4
MISCELLANEOUS.	6496	3.0	195		1.40	91		195	.130	8	18	[illegible]	65	.060	4
STRUCTURAL STEEL SCRAP.	34317	.20	69		TR	TR			.015	5	11	.45	154	.038	13
PIT SCRAP.	9005	.05	5		TR	TR			.015	1	2	[illegible]	4	.050	5
FOUNDRY SCRAP.	11800	.50	59		.25	29		62	.030	4	9	[illegible]	33	.050	6
T.S. GRANADA ORE (NAT.)	18680						5.41	1011	.051	10	23	[illegible]	24		
BERESFORD " "	1223						9.16	112	.088	1	2	.05			
MICHIGAN LIMESTONE	14000						.41	57	.005	TR.				.03	
CALCINED DOLOMITE	5000						2.20	110	.007	TR.				.06	
FLUORSPAR.	676						5.11	35		TR.					
SiO_2 FROM FCE STRUCTURE								188							
SiO_2 EXTRANEOUS.								50							
FERRO-MAN. IN LADLE.	747	6.3	47												
TOTAL ENTERING FCE			5186			1458		4683		334	763		2581		80
ALL STEEL. (INGOTS AND SCRAP) LADLE ANALYSIS.	175526	.15							.015	26	60	.45		.038	
ALL STEEL (INGOTS AND SCRAP) TAPPING ANALYSIS.	175526	.12	211		TR				.015	26	60	.25	439	.035	61
RUN OFF SLAG.	9611						22.81	2192	1.01	97	222	11.30	1086	.095	9
TAPPING SLAG.	15641						16.73	2617	.71	111	254	5.86	916	.204	.32
TOTAL LEAVING FCE								4809		234	536		2441		102
TOTAL IN PUT.			5186			1458		4683		334	763		2581		80
TOTAL OUT PUT			211					4809		234	536		2441		102
UN ACCOUNTED FOR.								+126		100	-227		-141		+22
METALLOIDS OXIDIZED.			4975	11592		1458				308			2148		

1	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
MATERIAL	% CaO	LBS CaO	% MgO	LBS MgO	% Fe	LBS Fe	% FeO	LBS FeO	% Fe_2O_3	LBS Fe_2O_3	% Al_2O_3	LBS Al_2O_3	% CaF_2	[illegible]	[illegible]
BESSEMER HOT IRON.						[illegible]									
BASIC " "						[illegible]									
" COLD "						[illegible]									
MISCELLANEOUS.						[illegible]									
STRUCTURAL STEEL SCRAP.						[illegible]									
PIT SCRAP.						[illegible]									
FOUNDRY SCRAP.						[illegible]									
T.S. GRANADA ORE (NAT.)	.88	164	2.77	517	53.16	10105	1.70	317	76.91	14367	1.74	325		7.08	[illegible]
BERESFORD " "	.50	6	.57	7	59.28	728	1.43	18	82.97	1015	2.47	30		7.7	[illegible]
MICHIGAN LIMESTONE	54.25	7595	1.03	144	.18	39					.15	21			[illegible]
CALCINED DOLOMITE	45.39	2299	30.80	540	.69	34					1.04	52		12.92	
FLUORSPAR.	3.1	21									.32		86.97		
SiO_2 FROM FCE STRUCTURE															
SiO_2 EXTRANEOUS.															
FERRO-MAN. IN LADLE.															
TOTAL ENTERING FCE		10085		2208		179268						428			
ALL STEEL. (INGOTS AND SCRAP) LADLE ANALYSIS.															
ALL STEEL (INGOTS AND SCRAP) TAPPING ANALYSIS.						174789									
RUN OFF SLAG.	21.03	2021	7.64	731		2162	26.75	2591	2.41	232	2.61	251			
TAPPING SLAG.	46.31	7243	8.06	1261		2063	13.85	2166	3.45	540	2.35	368			
TOTAL LEAVING FCE		9264		1995		4225						619			
TOTAL IN PUT.		10085		2208		179268						428			
TOTAL OUT PUT		9264		1995		179014						619			
UN ACCOUNTED FOR.		821		-213		-254						+191			
METALLOIDS OXIDIZED.															

THERMAL BALANCE SHEET OF FURNACE CHARGE.

HEAT ABSORBED

THERMO-CHEMICAL CHANGES.

REDUCTION OF OXIDES OF IRON.
HEAT OF FORMATION OF Fe_2O_3 = 3240 B.T.U.
" " FeO = 2430 B.T.U.

IN PUT.
Fe_2O_3 = 14367 LBS.
FeO = 317 LBS.
HEAT OF FORMATION
Fe_2O_3 = 14367 × 3240 = 46.55 × 10^6 B.T.U.
FeO = 317 × 2430 = .77 × 10^6 B.T.U.
TOTAL = 47.32 × 10^6 B.T.U.

OUT PUT.
RUN OFF SLAG. Fe_2O_3 = 232 × 3240 = .75 × 10^6 B.T.U.
FeO = 2571 × 2430 = 6.25 × 10^6 B.T.U.
TOTAL = 7.00 × 10^6 B.T.U.
TAPPING SLAG – Fe_2O_3 = 540 × 3240 = 1.75 × 10^6 B.T.U.
FeO = 2166 × 3240 = 5.26 × 10^6 B.T.U.
TOTAL = 7.01 × 10^6 B.T.U.
" = 14.01 × 10^6 B.T.U.

MOISTURE IN ORE
TOTAL WEIGHT OF ORE – 18680 LBS.
PERCENT MOISTURE – 8
TOTAL WATER 1494 LBS.
TOTAL HEAT TO MAKE STEAM AT 212° – 1494 × 1092 = 1.63 × 10^6 B.T.U.
SPECIFIC HEAT OF STEAM = .42 × .0003 (2800 + 212) = .81
HEAT IN SUPERHEAT = 1494 × 2588 × .81 = 3.13 × 10^6 B.T.U.
TOTAL = 4.76 × 10^6 B.T.U.

DECOMPOSITION OF LIMESTONE.
HEAT OF FORMATION $CaCO_3$ PER LB = 772 B.T.U.
TOTAL LIMESTONE = 15841 LBS.

DECOMPOSITION OF LIMESTONE CONT.
TOTAL HEAT REQUIRED = 15841 × 772 = 12.2 × 10^6 B.T.U.
MOISTURE 1.5 PERCENT = 238 LBS.
TOTAL HEAT TO MAKE STEAM = 238 × 1092 = .26 × 10^6 B.T.U.
HEAT IN SUPERHEAT – 238 × 2588 × .81 = .50 × 10^6 B.T.U.
TOTAL = 12.96 × 10^6 B.T.U.

DECOMPOSITION OF IMPROPERLY BURNED DOLOMITE
TOTAL WEIGHT OF DOLOMITE – 6110 LBS.
VOLATILE – 15.54 PERCENT = 951.
ASSUMED 98 PERCENT OF 951 = 932 EXISTS AS CO_2
TO DRIVE OFF CO_2 = 1756 B.T.U. PER LB.
TOTAL HEAT TO DRIVE OFF CO_2 = 932 × 1756 = 1.63 × 10^6 B.T.U.

THERMO-PHYSICAL CHANGE.

HOT METAL 106849 LBS. TEMPERATURE – 2474 DEG. F.
TAPPING TEMPERATURE – 3080 DEG. F. INCLUDES EMISSIVITY FACTOR
TEMPERATURE RISE (3080 – 2474) = 606° F.
SPECIFIC HEAT – 0.2
HEAT ABSORBED – 106849 × 606 × .2 = 12.95 × 10^6 B.T.U.
SCRAP – 55122 LBS. TEMPERATURE – 62 DEG. F.
MELTING TEMPERATURE SCRAP = 2795° F.
HEAT REQD TO BRING TO MELTING TEMP. = 55122 × 2733 × .16 = 23.9 × 10^6 B.T.U.
LATENT HEAT OF FUSION = 72 B.T.U.
TOTAL HEAT OF FUSION = 55122 × 72 = 3.96 × 10^6 B.T.U.
HEAT TO RAISE TO TEMP. BATH = 55122 (3080 – 2795) .2 = 3.14 × 10^6 B.T.U.
TOTAL HEAT = 31.00 × 10^6 B.T.U.

TOTAL HEAT IN MOLTEN SLAG
WEIGHT OF RUN OFF SLAG = 9611 LBS. TAPPING SLAG = 1564 LBS.
HEAT IN RUN OFF SLAG = 9611 × 900 = 8.65 × 10^6 B.T.U.
HEAT IN TAPPING SLAG. 15641 × 1066 = 16.67 × 10^6 B.T.U.
TOTAL HEAT = 25.32 × 10^6 B.T.U.

HEAT GENERATED.

OXIDATION OF CARBON WEIGHT = 4975 LBS.
HEAT OF FORMATION OF CO FROM C PER LB = 4374 B.T.U.
HEAT GENERATED = 4975 × 4374 = 21.80 × 10^6 B.T.U.

OXIDATION OF MANGANESE. WEIGHT = 2142 LBS.
HEAT OF FORMATION OF MnO = 2984 B.T.U.
HEAT GENERATED. 2984 × 2142 = 4.85 × 10^6 B.T.U.

OXIDATION OF SILICON. WEIGHT = 1458 LBS.
HEAT OF FORMATION OF SiO_2 = 11693 B.T.U.
HEAT GENERATED = 1458 × 11693 = 17.05 × 10^6 B.T.U.

OXIDATION OF PHOSPHOROUS. WEIGHT = 308 LBS.
HEAT OF FORMATION OF P_2O_5 = 10825 × 308 = 3.34 × 10^6 B.T.U.

HEAT OF FORMATION OF SLAG. WEIGHT = 25252 LBS.
HEAT GENERATED FROM
RUN OFF SLAG – 9611 × 114 = 1.096 × 10^6 B.T.U.
TAPPING SLAG – 15641 × 80 = 1.251 × 10^6 B.T.U.
TOTAL = 2.347 × 10^6 B.T.U.

HEAT ABSORBED – CONT

BASIC PIG – 15456 LBS. TEMPERATURE – 62 DEG. F.
MELTING TEMPERATURE – 2192 DEG. F.
HEAT REQUIRED TO BRING TO MELTING
TEMPERATURE – 15456 × 2130 × .167 = 5.5 × 10^6 B.T.U.
LATENT HEAT OF FUSION – 15456 × 41.4 = .640 × 10^6 B.T.U.
HEAT REQUIRED TO RAISE PIG FROM 2192 TO 3080
DEG. F = 15456 (3080 – 2192) × .2 = 2.75 × 10^6 B.T.U.
TOTAL = 8.89 × 10^6 B.T.U.

THERMAL BALANCE SHEET.

HEAT ABSORBED.	HEAT GENERATED.
REDUCTION OF OXIDES OF IRON = 33.31 × 10^6	OXIDATION OF CARBON. = 21.80 × 10^6
ABSORPTION OF MOISTURE OF ORE = 4.76 × 10^6	" " MANGANESE = 4.85 × 10^6
DECOMPOSITION OF LIMESTONE = 12.2 × 10^6	" " SILICON = 17.05 × 10^6
ABSORPTION OF MOISTURE OF LIMESTONE = .76 × 10^6	" " PHOSPHOROUS = 3.34 × 10^6
DECOMPOSITION OF DOLOMITE = 1.63 × 10^6	HEAT OF FORMATION OF SLAG = 2.350 × 10^6
HEAT IN MOLTEN SLAG = 25.32 × 10^6	BALANCE – HEAT TO BE
HEAT ADDED TO MIXER METAL = 12.95 × 10^6	SUPPLIED BY COMBUSTION OF GAS
" " " SCRAP = 31.0 × 10^6	IN FURNACE = 81.43 × 10^6
" " " BASIC PIG = 8.89 × 10^6	
TOTAL B.T.U. = 130.82 × 10^6	TOTAL B.T.U. = 130.82 × 10^6

OVER ALL THERMAL EFFICIENCY OF BATH.

THE TOTAL HEAT SUPPLIED IN THE FORM OF PRODUCER GAS = 572.0 × 10^6 B.T.U.

$$\text{THERMAL EFFICIENCY BASED ON TOTAL HEAT IN GAS SUPPLIED} = \frac{\text{NET HEAT USED BY MATERIALS IN BATH}}{\text{TOTAL HEAT IN GAS SUPPLIED}}$$

$$= \frac{81.43 \times 10^6}{572 \times 10^6} = 14.24\%$$

THE LOSS DUE TO CO IN THE FURNACE GASES = 4975 × 10206 B.T.U. = 50.5 × 10^6 B.T.U.

$$\text{THERMAL EFFICIENCY OF BATH AND FURNACE} = \frac{81.43}{572 + 50.5} = 13.10\%$$

FIG. 6—THERMAL AND CHEMICAL BALANCE SHEET OF FURNACE HEAT No. 24565. SEPTEMBER 26, 1922, SOUTH WORKS, ILLINOIS STEEL CO.

CHEMICAL BALANCE SHEET.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MATERIAL	WEIGHT IN POUNDS	% C	LBS C	LBS CO	% Si	LBS Si	% SiO_2	LBS SiO_2	% P	LBS P	LBS P_2O_5	% Mn	LBS MN	% S	LBS S
BASIC HOT IRON	114000	4.37	4982		.95	1083		758	.220	251	575	1.41	1607	.032	36
STRUCTURAL STEEL SCRAP	70000	.20	140		TR				.015	10	23	.50	350	.040	28
[illegible] ORE, [illegible]	19800						9.28	1837	.030	6	25		24		
[illegible] LIMESTONE	12000						.34	41	.002	1	3			.042	5
[illegible] DOLOMITE	6000						1.32	79	.004					.128	8
[illegible]	325						1.12	9						.004	
SiO_2 FROM FCE STRUCTURE.								176							
SiO_2 EXTRANEOUS															
FERRO-MAN. IN LADLE.	800	6.30	50												
TOTAL ENTERING FCE.			5042			1083		4462		272	624		1911		77
ALL STEEL (INGOTS AND SCRAP) LADLE ANALYSIS.	177300	.17	301		TR				.008	14	32	.45	798	.034	60
ALL STEEL (INGOTS AND SCRAP) TAPPING ANALYSIS	177300	.12	213		TR				.008	14	32	.20	354	.030	53
RUN OFF SLAG	10000						21.45	2145	1.06	106	243	9.25	925	.140	14
TAPPING SLAG	16100						5.25	2455	.89	143	327	4.80	773	.180	29
TOTAL LEAVING FCE			213					4600		263	580		2052		96
TOTAL IN PUT			5042					4462		272	624		1911		77
" OUT PUT			213					4600		263	580		2052		96
UNACCOUNTED FOR								+138		-9	44		+141		+19
METALLOIDS OXIDIZED			4829	11252		1081				258			557		

1	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
MATERIAL	% CAO	LBS CAO	% MGO	LBS MGO	% FE	LBS FE	% FEO	LBS FEO	% Fe_2O_3	LBS Fe_2O_3	% Al_2O_3	LBS Al_2O_3	% CaF_2	% [illegible]	% MOIST
BASIC HOT IRON						[illegible]									
STRUCTURAL STEEL SCRAP						[illegible]									
[illegible] ORE, [illegible]	1.60	317	1.24	273	51.76	10248	1.18	234	72.64	14383	1.16	229		3.12	8.00
[illegible] LIMESTONE	54.44	6532	.88	106	.20	24					.30	36			1.50
[illegible] DOLOMITE	48.58	2915	31.24	1874	.38	23					1.48	89		15.53	
[illegible]	.50	2	.58	3							[illegible]	9	95.52		
SiO_2 FROM FCE STRUCTURE.															
SiO_2 EXTRANEOUS															
FERRO-MAN. IN LADLE.															
TOTAL ENTERING FCE.		9796		2587		185958						352			
ALL STEEL (INGOTS AND SCRAP) LADLE ANALYSIS.						176127									
ALL STEEL (INGOTS AND SCRAP) TAPPING ANALYSIS						176666									
RUN OFF SLAG	25.20	2526	9.32	932		2044	23.16	2316	3.47	347	2.29	229			
TAPPING SLAG	47.20	7599	8.09	1202		2290	14.14	2277	4.61	742	1.95	314			
TOTAL LEAVING FCE		10119		2134		181000						543			
TOTAL IN PUT		9796		2589		185958						352			
" OUT PUT		10119		2134		181000						543			
UNACCOUNTED FOR		+323		-453		-4958						+184			
METALLOIDS OXIDIZED															

THERMAL BALANCE SHEET OF FURNACE CHARGE.

HEAT ABSORBED.

THERMO-CHEMICAL CHANGES

REDUCTION OF OXIDES OF IRON

HEAT OF FORMATION OF Fe_2O_3 = 3240 BTU

HEAT OF FORMATION OF FE O = 2430 B.T.U.

IN PUT.

Fe_2O_3 = 14383 LBS.

FE O = 234 LBS.

HEAT OF FORMATION.

Fe_2O_3 = 14383 X 3240 = 46.6 X 10^6 B.T.U.

FEO = 234 X 2430 = .59 X 10^6 BTU

TOTAL = 47.19 X 10^6 BTU

OUT PUT.

RUN OFF SLAG - Fe_2O_3 = 347 X 3240 = 1.12 X 10^6 B.T.U.

FEO = 2316 X 2430 = 5.63 X 10^6 B.T.U.

TOTAL = 6.75 X 10^6 B.T.U.

TAPPING SLAG - Fe_2O_3 = 742 X 3240 = 2.40 X 10^6 B.T.U.

FE O = 2276 X 2430 = 5.53 X 10^6 B.T.U.

TOTAL = 7.93 X 10^6 B.T.U.

TOTAL = 14.68 X 10^6 BTU

HEAT ABSORBED = 32.51 X 10^6 BTU.

MOISTURE IN ORE

TOTAL WEIGHT OF ORE = 19800 LBS.

PER CENT MOISTURE 8

TOTAL WATER 1584 LBS

TOTAL HEAT TO MAKE STEAM AT 212°F = 1092 X 1585 = 1.73 X 10^6 BTU

SPECIFIC HEAT OF STEAM = .42 + .000103 (2800 + 212) = .81

HEAT IN SUPERHEAT: 585 (2800 - 212) X .81 = 3.33 X 10^6 BTU

TOTAL = 5.06 X 10^6 BTU

THERMO-CHEMICAL CHANGES - CONT

DECOMPOSITION OF LIMESTONE

HEAT OF FORMATION OF $CaCO_3$ PER LB = 772 BTU

TOTAL LIMESTONE = 12000 LBS

TOTAL HEAT REQUIRED = 12000 X 772 = 9.26 X 10^6 B.T.U.

MOISTURE. 1.5 PERCENT = 180 LBS.

TOTAL HEAT TO MAKE STEAM = 180 X 1092 = .190 10^6 B.T.U.

HEAT IN SUPERHEAT = .46 X 10^6 BTU

TOTAL = .65 X 10^6 B.T.U.

TOTAL = 9.91 X 10^6 BTU

DECOMPOSITION OF IMPROPERLY BURNED DOLOMITE

TOTAL WEIGHT OF DOLOMITE = 6000 LBS.

VOLATILE - 15.54 PERCENT = 932 LBS

ASSUMED 98 PERCENT OF 932 = 913 LBS. EXISTS AS CO_2

TO DRIVE OFF CO_2 = 1756 B.T.U. PER LB.

TOTAL HEAT TO DRIVE OFF CO_2 = 913 X 1756 = 1.6 X 10^6 BTU

THERMO-PHYSICAL CHANGES.

HOT METAL = 114000 LBS. TEMPERATURE 2474°F.

TAPPING TEMPERATURE - 3080°F INCLUDES EMISSIVITY FACTOR

TEMPERATURE RISE = 3080 - 2474 = 606°F.

SPECIFIC HEAT = .2

HEAT ABSORBED - 111400 X 606 X .2 = 13.82 X 10^6 B.T.U.

SCRAP = 70000 LBS. TEMPERATURE - 62°F

MELTING TEMPERATURE OF SCRAP - 2795°F

HEAT REQUIRED TO BRING TO MELTING TEMP. 70000 X 2795 [illegible] 31.0 X 10^6 BTU

LATENT HEAT OF FUSION 72 B.T.U.

TOTAL HEAT OF FUSION = 70000 X 72 = 5.04 X 10^6 B.T.U.

HEAT TO RAISE TO TEMP OF BATH = 70000 (3080 - 2795) = 3.99 X 10^6 B.T.U

TOTAL HEAT = 40.03 X 10^6 BTU.

TOTAL HEAT IN MOLTEN SLAG.

WEIGHT OF RUN OFF SLAG = 10000 LBS. TAPPING SLAG 16100 LBS.

HEAT IN RUN OFF SLAG - 10000 X 900 = 9.0 X 10^6 BTU

HEAT " TAPPING " - 16100 X 1068 = 17.1 X 10^6 BTU

TOTAL = HEAT = 26.1 X 10^6 BTU.

HEAT GENERATED

OXIDATION OF CARBON. WEIGHT 4829 LBS.

HEAT OF FORMATION OF CO FROM C PER LB = 4374 B.T.U

HEAT GENERATED 4829 X 4374 = 21.20 X 10^6 BTU

OXIDATION OF MANGANESE. WEIGHT = 1557 LBS

HEAT OF FORMATION OF MNO = 2984 B.T.U.

" GENERATED. 1557 X 2984 = 4.64 X 10^6 B.T.U

OXIDATION OF SILICON. WEIGHT = 1081 LBS

HEAT OF FORMATION OF SiO_2 = 11693 BTU

GENERATED 11693 X 1081 = 12.63 X 10^6 B.T.U

OXIDATION OF PHOSPHOROUS. WEIGHT 258 LBS

HEAT OF FORMATION OF P_2O_5 = 10825 B.T.U

" GENERATED - 10825 X 258 = 2.77 X 10^6 B.T.U.

HEAT OF FORMATION OF SLAG. WEIGHT = 26100 LBS.

GENERATED FROM -

RUN OFF SLAG - 10000 X 108.6 = 1.086 X 10^6 B.T.U.

TAPPING SLAG - 16100 X 85.7 = 1.380 X 10^6 BTU

TOTAL = 2.47 X 10^6 B.T.U.

AUTHORITIES FOR CONSTANTS USED.

THERMO-CHEMICAL CHANGES.

IRON OXIDE REDUCTION — RICHARDS

DECOMPOSITION OF LIMESTONE — US BUREAU OF STANDARDS.

OXIDATION C MN SI P — RICHARDS - LE CHATELIER BETHELOT - THOMSEN.

FORMATION OF SLAG - CALCULATED USING RICHARDS VALUES.

THERMO-PHYSICAL CHANGE.

SP. HEAT - PIG IRON - .1665 - OBERHOFFER

" " SOFT STEEL - .16 - MEUTHER.

LATENT HEAT FUSION - PIG IRON - HÜTTER.

" " " - STEEL - AV VALUE - JETNER - RICHARDS - BRISKER

HEAT IN MOLTEN SLAG - SPRINGORUM.

THERMAL BALANCE SHEET.

HEAT ABSORBED.	HEAT GENERATED
REDUCTION OF OXIDES OF IRON 32.51 X 10^6	OXIDATION OF CARBON - 21.20 X 10^6
ABSORPTION OF MOISTURE OF ORE 5.06 X 10^6	" " MANGANESE - 4.64 X 10^6
DECOMPOSITION OF LIMESTONE 9.26 X 10^6	" " SILICON - 12.63 X 10^6
ABSORPTION OF MOISTURE OF LIMESTONE .65 X 10^6	" " PHOSPHOROUS - 2.77 X 10^6
DECOMPOSITION OF DOLOMITE 1.60 X 10^6	HEAT OF FORMATION - SLAG - 2.47 X 10^6
HEAT IN MOLTEN SLAG 26.10 X 10^6	BALANCE HEAT TO BE SUPPLIED
" ADDED TO MIXER METAL - 13.82 X 10^6	BY COMBUSTION OF GASES.
HEAT " " SCRAP - 40.0 X 10^6	IN FURNACE. 85.79 X 10^6
TOTAL B.T.U = 129.0 X 10^6	TOTAL B.T.U = 179.0 X 10^6

THERMAL EFFICIENCY OF BATH.

THE TOTAL HEAT SUPPLIED IN THE FORM OF PRODUCER GAS = 493 X 10^6 B.T.U.

THERMAL EFFICIENCY BASED ON $\dfrac{\text{NET HEAT USED BY MATERIAL IN BATH}}{\text{TOTAL HEAT IN GAS SUPPLIED}}$

$= \dfrac{85.29 \times 10^6}{493.0 \times 10^6} =$ 17.3 PER CENT.

THE LOSS DUE TO CO IN FURNACE GASES = 4711 X 10206 B.T.U = 48 X 10^6 B.T.U.

THERMAL EFFICIENCY OF BATH AND FURNACE $= \dfrac{85.29}{541.0} = 15.8$ PERCENT.

FIG. 7—HEAT BALANCE SHEET OF FURNACE, HEAT No. [illegible], SEPTEMBER [illegible]
SOUTH WORKS, ILLINOIS STEEL COMPANY.

AVERAGE TEMPERATURES.	DEG FAH
PRODUCER GAS IN GAS HEADER, BEFORE GAS VALVE.	1400
" FLUE, AFTER " "	1035
" AT PORT ENDS, AFTER CHECKERS.	1780
AIR FOR COMBUSTION, BEFORE AIR VALVE	102
" " " CHECKERS.	625
" AT PORT ENDS, AFTER CHECKERS.	2272
WASTE GASES LEAVING FURNACE	2374
" " CHECKERS.	1283
" BEFORE BOILER DAMPER.	126[illegible]

AVERAGE GAS ANALYSIS LOCATION	CO_2	O_2	CO	H	CH_4	C_2H_4	N
PRODUCER GAS IN HEADER BEFORE GAS VALVE	8.96	0.0	16.23	11.3	2.86	0.33	5[illegible]
" BEFORE FURNACE PORTS.	10.0	0.0	15.6	12.0	2.50	0.10	59.8
WASTE GAS LEAVING FURNACE.	14.3	1.7	2.57				81.43
" " CHECKERS	13.1	4.4	1.0				81.[illegible]
" AT BOILER DAMPER	13.8	5.1	0.0				81.1[illegible]

HEAT CONTRIBUTED	
PRODUCER GAS	MILLION B.T.U.
TOTAL WEIGHT OF DRY GAS - 209,500 LBS.	
CALORIFIC VALUE OF GAS - B.T.U. PER CU.FT. = 124.8	379.0
SENSIBLE HEAT OF GAS	83.1
MOISTURE IN GAS. = 18,000 LBS.	
TOTAL HEAT IN MOISTURE.	17.7
SUPER HEAT IN "	13.2
TOTAL.	493.0
CHEMICAL AND THERMAL CHANGES IN THE BATH.	
NET HEAT ABSORBED REFER TO SHEET - III 129.0 - 43.71 MILLION B.T.U.	85.29

REGENERATION	
GAS IN REGENERATOR	MILLION B.T.U.
TOTAL WEIGHT OF DRY GAS - ENTERING CHECKER = 209,500 LBS.	
CALORIFIC VALUE OF GAS - B.T.U. PER CU.FT. = 124.8	379.0
SENSIBLE HEAT OF GAS.	62.8
TOTAL HEAT IN MOISTURE.	17.7
SUPER HEAT IN MOISTURE.	9.9
TOTAL -	469.4
TOTAL WEIGHT OF DRY GAS - LEAVING CHECKER = 214,400 LBS.	
CALORIFIC VALUE OF GAS.	362.0
SENSIBLE HEAT OF GAS	113.6
TOTAL HEAT IN MOISTURE.	19.1
SUPER HEAT IN MOISTURE.	19.3
TOTAL -	514.0
AIR IN REGENERATOR.	31.7
HEAT IN AIR ENTERING CHECKER.	2.1
" MOISTURE IN AIR ENTERING CHECKER.	
TOTAL -	38.8
HEAT IN AIR LEAVING CHECKER.	160.6
HEAT IN MOISTURE IN AIR LEAVING CHECKER.	4.8
TOTAL -	165.4

SPECIFIC HEATS AT CONSTANT PRESSURE.	
OXYGEN	.2104 + .0000104 T °F.
CARBON DIOXIDE.	.19 + .00006 T °F.
HYDROGEN	3.37 + .00017 T °F.
WATER VAPOR	.42 + .000103 T °F.
NITROGEN	.2405 + .0000109 T °F.
CARBON MONOXIDE	.2405 + .0000109 T °F.
METHANE	.38 + .000128 T °F.
C_2H_4 ETHYLENE	.46 + .00017 T °F.
AIR	.2336 + .00001134 T °F.

OVER ALL THERMAL EFFICIENCY OF THE UTILIZATION OF THE COAL BURNED.

YEAR	MILLION B.T.U. IN COAL	MILLION B.T.U. UTILIZED IN MAKING STEEL	%	NET MILLION B.T.U. UTILIZED BY WASTE HEAT BOILER	%	TOTAL MILLION B.T.U. UTILIZED	PERCENT OF TOTAL SUPPLIED	PERCENT INCREASE
192[illegible] 79 TON HEAT	612	81.41	13.3	NO BOILER.		81.41	13.3	
1922 79 TON HEAT	531	85.29	16.1	105	19.8	190.29	35.8	170
PROPOSED 90 TON FCE 90 TON HEAT	686	118.8	17.3	BOILER AND ECONOMIZER 145	21	263.8	38.3	193

RECUPERATION	
WASTE GAS IN CHECKERS	MILLION B.T.U.
TOTAL WEIGHT OF DRY WASTE GASES LEAVING FURNACE = 517,500 LBS.	
" " " MOISTURE LEAVING FURNACE. = 48,560 LBS.	
CALORIFIC VALUE OF WASTE GASES LEAVING FURNACE. - DUE TO CO CONTENT	53.[illegible]
SENSIBLE HEAT OF WASTE GASES.	334.[illegible]
TOTAL HEAT IN MOISTURE OF WASTE GASES.	48.[illegible]
SUPER HEAT IN " " " "	69.[illegible]
TOTAL -	506.0
TOTAL WEIGHT OF DRY WASTE GASES LEAVING CHECKERS = 613,000 LBS.	
CALORIFIC VALUE OF WASTE " " " DUE TO CO LEAVING GAS CHECKERS	23.[illegible]
SENSIBLE HEAT OF WASTE GASES	[illegible]
TOTAL HEAT IN MOISTURE OF WASTE GASES.	48.[illegible]
SUPER " " " " " "	[illegible]
TOTAL -	230.[illegible]
TOTAL WEIGHT OF DRY WASTE GASES AT BOILER DAMPER [illegible]	
CALORIFIC VALUE OF WASTE GASES AT BOILER DAMPER.	
SENSIBLE HEAT " " " " " "	192.[illegible]
TOTAL HEAT IN MOISTURE OF WASTE GASES AT BOILER DAMPER	[illegible]
SUPER " " " " " " " " "	30.[illegible]
TOTAL -	270.[illegible]
SENSIBLE HEAT OF AIR LEAKAGE AT CHECKERS INTO WASTE GASES. - MOISTURE NEGLECTED	29.[illegible]
TOTAL -	29.0

RADIATION.	
GAS AND AIR CHECKERS	MILLION B.T.U.
HEAT ABSORBED FROM WASTE GASES.	216.0
HEAT TAKEN UP BY PRODUCER GAS.	45.6
HEAT " " " AIR FOR COMBUSTION	131.6
TOTAL HEAT TAKEN UP BY AIR AND GAS	177.2
HEAT RADIATED FROM CHECKER CHAMBERS, SLAG POCKETS, AND UPTAKES.	38.8
EFFICIENCY OF REGENERATION. 82%	
COMBUSTION CHAMBER AND PORT ENDS.	
HEAT IN GAS AT PORT ENDS.	[illegible]
" " AIR " " "	165.40
TOTAL -	679.[illegible]
HEAT IN WASTE GASES LEAVING FURNACE.	506.0
NET HEAT ABSORBED IN BATH	[illegible]
TOTAL -	[illegible]
RADIATION FROM BATH AND PORT ENDS	[illegible]

HEAT ABSORBED BY COOLING WATER	MILLION B.T.U.
AVERAGE GALLONS OF COOLING WATER PER 24 HRS. ON FURNACE PROPER INCLUDING	
PORTS - DOORS - BUCKSTAYS AND ETC. = 792,000.	
AVERAGE TEMPERATURE RISE OF WATER - 23.4 DEG. F	
HEAT TRANSFERRED TO WATER.	[illegible]
AVERAGE GALLONS COOLING WATER TO GAS VALVE PER 24 HRS. = 38,180	
AVERAGE TEMPERATURE RISE OF WATER. - 89.5 DEG. F	
HEAT TRANSFERRED TO GAS VALVE COOLING.	10.75
AVERAGE GALLONS COOLING WATER TO STACK DAMPER PER 24 HRS. = 15,820	
AVERAGE TEMPERATURE RISE - 24.0 DEG. FAH.	
HEAT TRANSFERRED TO STACK DAMPER COOLING WATER.	1.21
TOTAL -	82.56

HEAT BALANCE SHEET OF FURNACE.

HEAT - CONTRIBUTED.	MILLION B.T.U.	%	HEAT - DISTRIBUTED.	MILLION B.T.U.	% OF PRODUCER GAS	% OF IN COAL	[illegible] PER [illegible]
CALORIFIC VALUE OF FUEL	379.0	76.8	TOTAL HEAT RADIATED BY COMBUSTION CHAMBER AND PORT ENDS	58.[illegible]		[illegible]	[illegible]
SENSIBLE HEAT OF PRODUCER			HEAT ABSORBED BY COOLING WATER COMB. CHAMBER " " "	70.60	14.3		
GAS AND MOISTURE.	114.0	23.2	NET HEAT RADIATED FROM BATH AND PORT ENDS	17.51	3.58		
TOTAL -	493.0	100.0	HEAT RADIATED FROM GAS AND AIR CHECKERS AND UPTAKES	38.8	7.85	7.3	42.6
			" ABSORBED BY COOLING WATER ON GAS VALVE.	[illegible]	[illegible]	2.0	11.4
			" " " " " STACK DAMPER	[illegible]	[illegible]	[illegible]	[illegible]
			" IN WASTE GASES TO BOILER.	270.0	54.05	5[illegible]	29[illegible]
			NET HEAT ABSORBED IN BATH (129 - 43.7)	85.29	17.30	[illegible]	[illegible]
			TOTAL -	494.0	100.1		
			DIFFERENCE IN TOTAL B.T.U. IN GAS AS COMPARED WITH B.T.U. IN COAL	38.0		7.2	42.0
			360 Bo.H.P. (GROSS) DEVELOPED BY WASTE HEAT BOILER		TOTAL -	100.4	5[illegible]
			345 " " (NET) " " " "				
			DEDUCTING FAN TURBINE STEAM BUT CREDIT FOR				
			EXHAUST FOR HEATING FEED WATER	105.0		[illegible]	
			HEAT IN STEAM FOR BLOWING THE 5 PRODUCERS	18.0			
			NET HEAT IN STEAM AVAILABLE FOR USE OUTSIDE O.H. DEPT.	87.	16.4	16.4	
			COAL EQUIVALENT OF THIS STEAM BASED ON ITS				
			GENERATION BY A COAL FIRED BOILER HOUSE				
			OPERATING AT 70% EFFICIENCY				137.0

crucible (bottom) was practically free from slag and metal both at the beginning and end of the test heat.

All pyrometers were calibrated before the test at the Company's pyrometer laboratory. During the test the pyrometers measuring the temperature of the ingoing and outgoing gases were checked by an optical pyrometer sighted on silica and fire brick closed tubes which projected into the path of the gases.

A large orifice was installed in a 42-inch air duct leading to the air valve of the furnace. A very sensitive and accurate air meter which recorded the differential pressure across the orifice was loaned us through the courtesy of The Bailey Meter Company of Cleveland, Ohio.

Conclusion

In the preceding text we have dealt to a large extent with such theoretical and general considerations as seemed to us supremely important in open-hearth furnace design and operation. Such important matters as fuels, gas producer design and operation, slags and the relative value of different processes and their effects upon efficiency, necessarily remain untouched.

We now propose to consider briefly the results obtained from our investigation.

Fig. 4 gives the log of the test carried out by the authors, September 26, 1922, which shows in sequence all operations during the entire heat from which the detailed results were calculated.

Fig. 5 is the thermal and chemical balance of a furnace charge, for a type of furnace used at these works during the year 1912, the data for which was collected during a special investigation of another subject.

Fig. 6 is the thermal and chemical balance of the furnace charge determined from the observations as given by Fig. 4.

Fig. 7 is the heat balance, the data for which was also derived from Fig. 4, and by means of which the various items of heat distribution are shown.

Fig. 8 is a graphic record of the principle temperatures, air flow to furnace and coal log covering the period from tap to tap.

We now propose to consider briefly the salient features shown by the above sheets.

The heat balance (see Fig. 7) shows a total heat input of 531 million B. T. U. in the coal fired in the gas producers, of which 493 million B. T. U. was delivered to the furnace gas valve, no allowance being made for the tarry vapor content of the gas.

Of this 531 million B. T. U., the principle losses were:

Losses	Millions of B. T. U.	Loss in Per Cent of Coal Fired
Carbon monoxide in waste gas sampled at port ends	53.5	10.01
Heat radiated from checker chambers, slag pockets and uptakes	38.8	7.3
Total heat absorbed by cooling-water (not including gas valve)	71.75	13.5
Heat absorbed by gas valve	10.75	2.0
Heat in waste gas to boiler	270.00	51.0

The heat in useful work in the steel produced amounted to 85.29 million B. T. U. or 16.1 per cent of the B. T. U. contained in the coal fired. The net heat recovered by the waste heat boiler, after deducting the heat in the steam used for blowing the five gas producers was 87 million B. T. U. or 16.4 per cent of the B. T. U. in the coal. The large losses in cooling-water have been discussed in a preceding part of the paper.

The apparent loss in the form of unburned carbon monoxide is in part recovered by secondary combustion in the checker chamber and largely appears as additional heat in the waste gases utilized by the boiler. This large loss to the furnace is uneconomical from the standpoint of furnace efficiency, and may be corrected

in a large measure by improving melting chamber combustion.

Some 38.8 million B. T. U. are lost by radiation from checker chambers, slag pockets and uptakes, and we would expect in the 100-ton furnace to prevent a portion of this by insulation of the checker chamber walls.

The gases leaving the waste heat boiler can be further utilized by means of a feed water economizer to the extent of approximately 8 per cent additional steam generation, as demonstrated by a recent installation at these works.

Figs. 5 and 6 which show in detail the efficiency of two different types of furnaces should by the data given be self-explanatory. It will be noted on both these sheets, that two thermal efficiencies are shown, the higher representing bath efficiency based upon the fact that, by oxidation, the carbon content of the bath is reduced to carbon monoxide and contributes heat to the bath by such a thermo-chemical reaction. The lower efficiency figure is based upon the belief, that the carbon monoxide thus produced, after escaping from the bath, should in a large measure be burned in the melting chamber. Upon this basis, we feel justified in assuming that if the major portion of carbon monoxide so produced is not burned in the melting chamber, it indicates defective combustion and naturally a reduced efficiency. For these reasons, we have charged against the furnace in the low efficiency figure the equivalent energy in the carbon monoxide if burned to carbon dioxide.

Referring again to Fig. 8 and Fig. 4, it will be noted, that the air flow as registered by meter indicated unequal air delivery to the opposed air chambers to the extent of approximately 20 per cent; and in addition failed to show any increase in the air input over those periods during which the greatest amount of coal was fired and the maximum volume of carbon monoxide was being evolved by the bath reactions. But what is more striking, the recorded air flow shows a reduction in the air

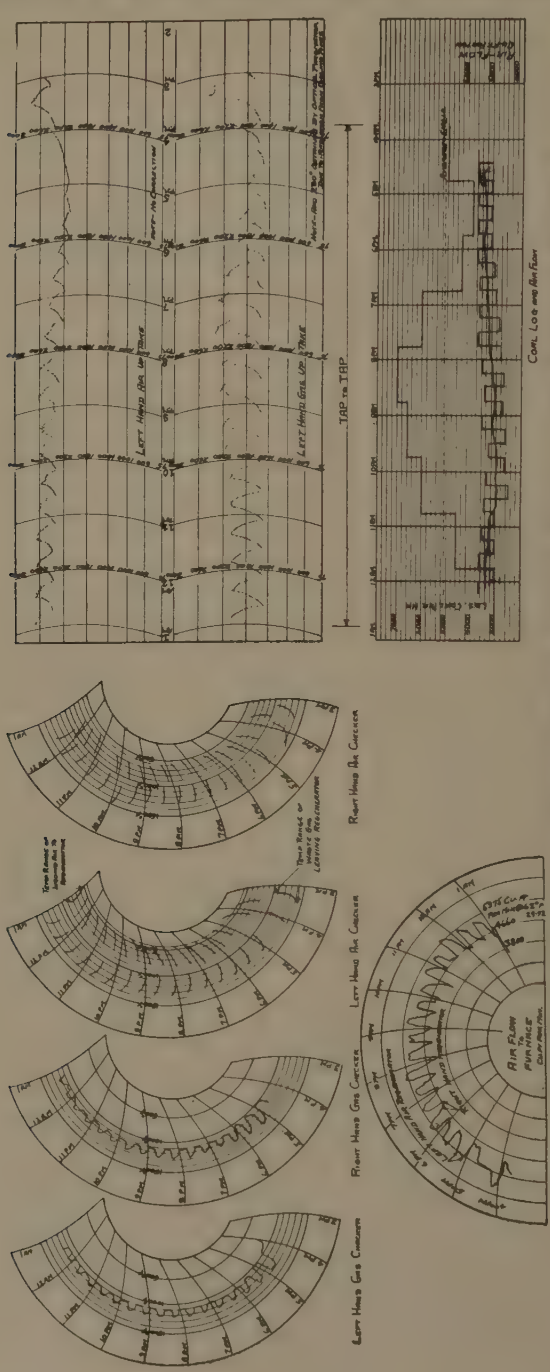

Fig. 8—Graphs of Temperature, Coal Consumption and Air Flow, Heat No. 24565, September 26, 1922.

delivered during those previously named periods, presumably due to a lack of stack capacity on the outgoing end of the combustion chamber. It will be noted that in the 100-ton furnace (Fig. 3) an attempt is made to partially overcome this deficiency, by increasing the outlet area of the melting chamber approximately 100 per cent, through the raising of a damper at this point.

To further an increase of efficiency in this respect, we propose to install a fan or other mechanical means of delivering air, and which is automatically controlled to supply air for effective combustion. The automatic control feature will supply air in proportion to the fuel consumed. This air control will operate in combination with an automatic control of the removal of the waste gases which must maintain a balanced draft in the melting chamber.

A reference to Fig. 4 and Fig. 8 shows emphatically the need of providing a means of supplying the proper amount of air for combustion as demanded by the ratio of fuel burned. It is apparent from the analysis of the waste gases shown in Fig. 4 and the record of the air flow meter, Fig. 8, that the stack effect of the air regenerators and uptakes cannot be depended upon at all times to supply the required air for efficient combustion. Needless to say this condition will exist regardless of the means employed for mixing the two gases before combustion takes place, although it is of course necessary to produce an intimate mixture of the two gases as well in order to obtain efficient combustion.

Fig. 3 shows a 100-ton furnace to tap 110-ton heats with a modern gas producer plant, waste heat boiler and economizer. The port construction of the furnace as shown is purely theoretical, the soundness of the design and expected results to be proved by actual construction and operation.

The following table gives a comparison of the important dimensions of the three types of furnaces discussed; and as a matter of additional interest we show

the same data for the 100-ton furnace designed by Mr. Fred Clements of Rotherham, England.

PRINCIPAL DIMENSIONS OF FURNACES REFERRED TO IN TEXT

	1912			1922			100 TON FURNACE			CLEMENT'S 100 TON FCE.		
DISTANCE BETWEEN GAS PORT FACES IN FEET	39			43			54			48		
WIDTH BETWEEN FRONT AND BACK WALLS	13'-3"			13'-3"			15'-7.5"			16'		
LENGTH OF HEARTH	32'			32'			42'			38'0"		
SQUARE FEET OF HEARTH AREA PER TON OF INGOT	5.73			5.73			6.75			6.08		
AREA OF GAS PORT OR PORTS IN SQUARE FEET	4.7			4.7			2-3.4=6.8			3.0		
AREA OF AIR PORT IN SQUARE FEET	24.5			38			42			7.8		
AREA OF MIXING THROAT INCOMING IN SQUARE FEET	46.9			20			2-9.7=19.4			ABOUT 19		
AREA OF MIXING THROAT OUTGOING IN SQUARE FEET	46.9			20			39.8			ABOUT 19		
LENGTH BETWEEN MIXING THROATS	30'-11"			37'-4"			50'-0"			37'-0"		
	AIR	GAS	TOTAL	AIR	GAS	TOTAL	AIR	GAS	TOTAL	AIR	GAS	TOTAL
TOTAL WEIGHT OF CHECKERWORK—(AIR AND GAS CHAMBER IN LBS.	146316	106959	243275	145500	83100	228600	294573	184788	47936	124355	93300	217655
CUBIC FEET OF CHECKER WORK GAS AND AIR.	2502	1829	4331	3195	1829	5024	5872	3684	9556	1891	1509	3400
TOTAL EXPOSED SURFACE IN SQUARE FEET—(AIR AND GAS CHAMBER	8982	6566	15548	18157	10391	28548	32216	20925	53141	12149	9063	21212
EXPOSED SURFACE IN SQUARE FEET PER CUBIC FOOT OF CHECKERWORK	3.59	3.59		5.68	5.68		5.08	5.08		6.2	6.2	
AVAILABLE AREA OF OPENING AT TOP OF AIR CHECKER IN SQUARE FEET	75			100			157			26.2		
AVAILABLE AREA OF OPENING AT TOP OF GAS CHECKER IN SQUARE FEET		55			55			92.5			16.2	
AREA OF DOWNTAKES IN SQUARE FEET	23.0	6.25	29.25	25.3	7.9	33.2	42.0	2-9-18	60	15.0	6.6	21.6

The utility of a theory or theories can in general be said to be proven, or not proven, by the commercial result of their application over long periods of time; and we submit the following figures of pounds of coal per ton of ingots produced at these works during the periods covered by the text, as further proof of the soundness of the theories advanced.

UNIVERSAL No. 4 MINE RUN COAL

B. T. U. per pound by calorimeter = 11,445

Proximate Analysis (natural) per cent.

Volatile	Fixed Carbon	Ash	Moisture	Sulphur
35.35	44.50	7.60	12.55	1.54

Period of 1912, pounds of coal per ton of ingots = 750.

Period of 1914, subsequent to improvement in checker work, pounds of coal per ton of ingots = 684.

Period of 1922, subsequent to improved port and melting chamber design, pounds of coal per ton of ingots = 596.

Had the works been fortunate enough to have been supplied at all the periods named with what may be termed a standard gas coal, the pounds of coal per ton of ingots would be shown in the following figures which

are confirmed by the actual operating results obtained during fairly long periods, when we were supplied with such coal.

LYNCH MINE RUN COAL

B. T. U. per pound calorimeter = 14,000

Proximate Analysis (natural) per cent.

Volatile	Fixed Carbon	Ash	Moisture	Sulphur
36.65	56.45	4.25	2.65	0.54

Period of 1912 = 600 pounds
Period of 1914 = 548 pounds
Period of 1922 = 477 pounds

In closing it is desired to express our appreciation of the care and interest taken by all participants in this work, both in observation, tabulation and drawings.

Vice-President Topping: The discussion of this paper will be by Mr. S. S. Ball, Bethlehem Steel Company, Bethlehem, Pa.

Discussion by S. S. Ball

Superintendent, Open-Hearth Departments Nos. 1 and 3, Lehigh Plant, Bethlehem Steel Company, Bethlehem, Pa.

The very interesting paper of Messrs. McDermott and Kinney delves into a subject which daily assumes greater economic importance due to the increasing cost of fuels.

The fuel wasted in the open-hearth plants of the country, due to lack of accurate knowledge of how great are the heat losses and where these occur, must total a tremendous amount. Compared with the fuel efficiency of the modern steam boiler plant, the fuel efficiency of the open-hearth plant is at about the stage as steam transmission was when pipes remained uncovered. In order to reach the same relative efficiency, the open-hearth plant must undergo the same careful and scientific study as the boiler plant. Facts and figures must be made available. The paper which is under discussion presents many of these facts and figures. From our own expe-

rience, we can add to and corroborate this data perhaps in some useful way.

Temperatures were taken on a producer gas furnace of 50 tons nominal capacity, tapping 75-ton heats, after 268 heats on the roof and 765 heats on the checkers. The furnace was being charged with all cold stock and was making shamefully slow time. The travel of the gas was from the producer house through 100 feet of underground sewer up into a pipe line which had branches leading to the gas valves at each end of the furnace.

The temperature drop from one end of the gas sewer to the other end was fifty degrees. The loss in temperature in the branches of the gas main leading to the valves, however, was more considerable. These branches were each about forty feet long and temperatures, taken where they were connected to the valves, showed that while the gas was traveling through one branch, the temperature in the other branch was dropping 400 to 600 degrees during a half-hour period. Upon reversal it required about twenty minutes for the temperature in the latter branch to build up to normal. In other words, there was an average loss of about 200 degrees in the sensible heat of the gas at this point in its travel, due to the design and the construction of the gas mains. The remedy is obvious; make the gas mains as short as possible and put heat insulation between the fire brick lining and the boiler plate.

Temperatures taken in the gas flues, simultaneously with temperatures of the gas entering the valve, showed a loss of 300 degrees in heat between these points. Since the same valve was used to handle the waste gases traveling from the furnace to the waste heat boilers, there was also a material loss of heat available for making steam.

The valve in question was of a common type, which brings the gas in direct contact with a considerable water surface. Mechanically, this type of valve is good, but it has a low thermal efficiency.

The furnace was equipped with water-cooled ports. The temperature of the waste gases passing from the furnace showed 200 to 300 degrees lower in the gas uptake than at the same relative point in the adjoining air uptakes. This indicates that the water-cooled port was

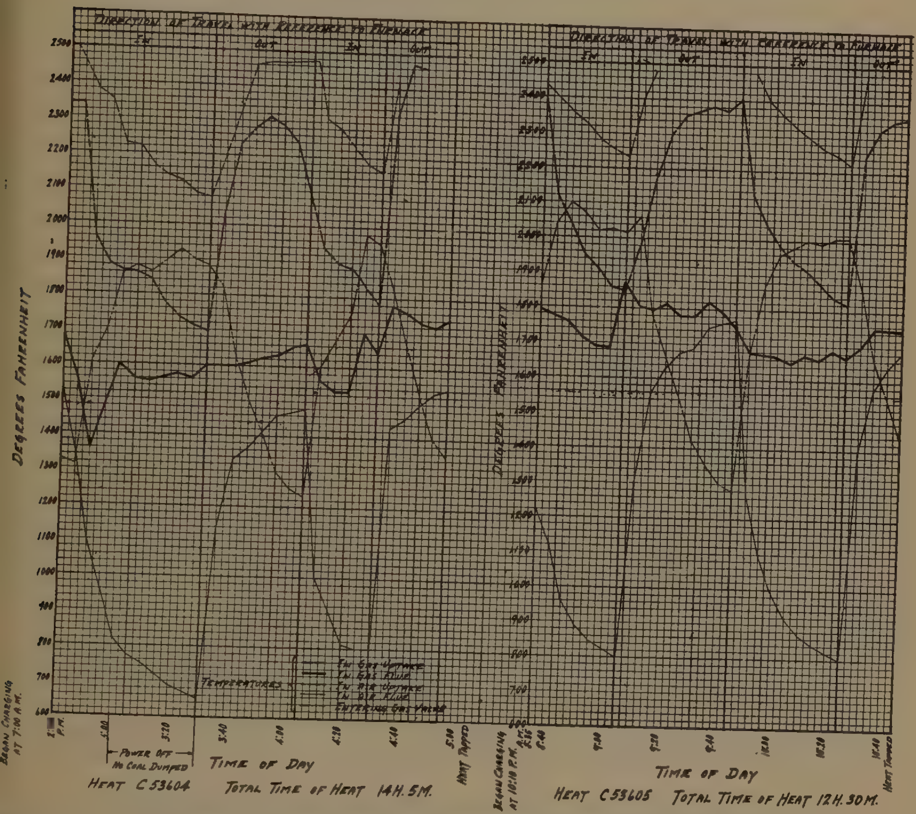

Fig. 1—Chart showing temperatures taken during the working of two heats in the open-hearth furnace described in the text.

lowering by 200 to 300 degrees the temperature of the incoming gas as well as the outgoing waste gases.

The above are the main facts brought out as regards heat losses in the travel of the gas from producer to furnace, and are losses due mainly to design and construction.

The accompanying chart brings out additional heat losses due to faulty regeneration. Temperatures were taken on five heats, but the plots given represent closely the results obtained on all five.

Some points of note on this chart are:

First: the producers are being run excessively hot.

Second: gases in the outgoing flues are leaving the regenerators at a very high temperature, proving that the checker work is not functioning properly.

Third: the air temperature in the ingoing air uptake drops off rapidly, confirming the fact that the checker work is not storing sufficient volume of heat.

One conclusion to be drawn from the two latter points is that a run of 765 heats, on the air checkers at least, without renewal, is undoubtedly too long for efficient working.

The 100-ton furnace proposed by Messrs. McDermott and Kinney has been devised on principles which we fully endorse, and would emphasize as desirable, namely, a minimum of water-cooling in valves and ports; heat insulation in flues and gas mains; automatic control of the air supply so that the air is delivered in proportion to the fuel to be consumed; and a port construction to give quick and intimate mixture of the air and fuel.

The use of these principles in open-hearth furnace construction will go a long way toward reaching the goal of high thermal efficiency.

It is our observation that the attention of the open-hearth superintendent has been necessarily devoted largely to maintaining an uninterrupted operation and to securing a maximum tonnage output. Much effort has been spent in increasing the life of the furnace and decreasing refractory costs. That the improvement in furnace tonnage and refractory cost has been accompanied by ever increasing fuel economy is not to be overlooked; but there can be little doubt that the maximum attainable fuel economy has not yet been reached.

Since the largest single item in open-hearth conversion

cost is fuel, any advance in the art that neglects thermal efficiency is incomplete and unsatisfactory.

In order to achieve the best thermal efficiency we believe it necessary that temperatures be taken on all furnaces at regular intervals and at fixed locations, so that the open-hearth superintendent will always have at hand data on the various conditions from a scientific thermal standpoint. This would be both interesting and profitable.

In order, however, that the information obtained be suitable for comparison with work of a similar nature, carried on throughout the steel industry, a standard method of obtaining and tabulating the data should be prescribed and we believe that given the standard method, observations would soon become general and their results, if made available, would be of very great benefit to the industry.

The discussion by correspondence offered by Mr. Francis L. Toy (see program on page 284) was not received in time for insertion in this volume. Meanwhile another discussion by correspondence has been submitted by Mr. Waldemar Dyrssen and is given below in place of Mr. Toy's discussion.

Discussion by Waldemar Dyrssen

Metallurgist, United States Steel Corporation, New York

There can be no question about the great practical value of the timely paper of Messrs. Kinney and McDermott and all open-hearth men should study it carefully. The design of the 100-ton furnace, representing the latest tendency in the United States, is very interesting, especially in comparison with Mr. Clements' 100-ton furnace. In many respects they are diametrically opposed to each other, especially in regard to design of checkers, area of uptakes and amount of water-cooling. An open-hearth

man naturally will ask the questions "Which is the best furnace?" and "Is any open-hearth furnace built within these two extremes also satisfactory?" One of the main reasons for the wide divergency of opinion, I think, is that the open-hearth has developed along other lines here in America than in England. High yearly production, short time per heat and short rebuilding time are more desired here than high thermal efficiency only. Mr. Clements' 60-ton furnace makes the heats in approximately 50% longer time and burns less than half as much fuel per minute as compared to the 80-ton South Chicago furnace. These furnaces are of practically the same size, and if only 60-ton heats were made in the South Chicago furnace, the time per heat would have been still shorter. This is so much more remarkable, as the gas in South Chicago is very poor. There can hardly be any question about the American 100-ton furnace being able to burn a much greater amount of fuel per minute, to make the heats in much shorter time, and to show better cost per ton of ingots than the English furnace, even if the English furnace probably would show a higher thermal efficiency. In this connection, it is proper to point out that the waste heat boiler is one of the most necessary accessories of the modern open-hearth furnace, as it raises the thermal efficiency tremendously and makes the actual thermal efficiency of the furnace proper of much smaller consequence. I think, therefore, that the lines followed in the American design, with waste heat boiler installation, are to be preferred.

I find, however, in looking over the Chemical and the Heat Balance sheets, Figs. 6 and 7 of Kinney and McDermott paper, that there are a few points which are of much theoretical and also of practical importance which need to be clarified and in some cases corrected.

1.—On Fig. 7 is an item in the heat balance called "Net heat radiated from bath and port ends 17.51×10^6 B.T.U." This is entirely too low. From electric furnace practice, we know fairly accurately that the radiation loss

in a steel furnace of ordinary wall thicknesses and materials is from 3,000 to 3,500 B.T.U. per square foot of outside surface per hour. The bottom of the hearth can hardly radiate less than 700 to 1,000 B.T.U. A rough estimate of the heat radiated from the melting chamber and port ends with due consideration of the front walls and the doors, which are water-cooled, would reveal that the loss must be at least 60×10^6 B.T.U. A careful scrutiny of the figures reveals that this is largely due to the fact that the CO from the C in the bath could burn to CO_2. This is not taken into account in the available heat in the melting chamber, but all the calorific heat of CO, even the CO from the bath in the waste gases, is nevertheless included in the total heat in these gases. By this method of figuring the melting chamber and the whole furnace has been robbed of approximately 50×10^6 B.T.U. in the heat balance.

2.—Another source of error in the heat balance is due to the fact that in the heat absorbed by the charge the latent heat in, and the superheat of, the moisture in the charge is also taken into account. This heat is, however, also accounted for in the waste gases leaving the melting chamber and is therefore accounted for twice. It is, of course, perfectly proper that the total heat in the moisture should be taken into account in calculating the heat to the bath, and the superheating of the CO_2 from the limestone, dolomite, etc., should also have been counted for that matter. The heat actually absorbed by the bath or charge cannot, however, be taken as a basis for a general heat balance without large errors creeping in.

In a general heat balance *all* the heat input and output of the furnace as a whole should be balanced against each other, if errors are to be avoided. After a complete heat balance is made up, bath efficiency or any other efficiency may be calculated.

3.—An item that influences the bath efficiency very much is the heat absorbed by the reduction of Fe and

FeO from ore. In this item a mistake has been made, as the heat of formation used for Fe_2O_3 and FeO are per pound of metallic Fe, but calculated per pound of Fe_2O_3 and FeO. The corrected figure for heat absorbed would be 21.9×10^6 B.T.U., instead of 32.51×10^6 B.T.U. (see Fig. 6). This mistake in itself would lower the bath efficiency from 17.3% to 15.2%. It has, however, also been assumed that all the Fe unaccounted for, or 4,958 pounds, is in the form of metallic Fe, whereas a more reasonable assumption would be that a great part of this is lost in the gases as Fe_2O_3. From the quality of ore used and from other known conditions, we are justified in assuming that about 2,000 pounds of Fe is lost as Fe_2O_3. This would lower the heat absorbed by the reduction of Fe and FeO from 21.9×10^6 to 15.4×10^6 B.T.U. and the bath efficiency would be 13.9%. This shows the importance of this item and also how relatively small changes and errors in the calculation of the heat absorbed by the bath influence the bath efficiency. This makes comparisons between furnaces on this basis very hazardous.

4.—Another item which is nearly always overlooked, that must be included in the heat from the gases to the bath, is the heat absorbed by the partial reduction in the bath of the CO_2 from the limestone. Practical experiments with limestone and burnt lime have established that limestone has a considerable oxidizing effect on the charge and for practical purposes it can be assumed that two-thirds of CO_2 in the limestone is broken up into CO.

5.—In the calculation of the heat in the producer gas, waste gases and air, gross heat values have been used; that is, the heat that could be extracted if all the water vapor were condensed to water is also included. This makes it necessary to assume that even atmospheric air at 62°F. has a heat value of about 10 B.T.U. per pound, or in this case, a total of approximately 3×10^6 B.T.U. The use of gross heat values makes, for instance, the heat content of the waste gases to the boiler 54.65% of the fuel. However, about 10% of the heat in the fuel is lost, as we

cannot recover the heat in water vapor going into the clouds formed from these gases. In my opinion, it is better practice to adopt the United States Steel Corporation's standard and use net heat values throughout as gross values are in many cases extremely misleading.

6.—On Fig. 7 it has been calculated that the waste gases leaving the checkers contain 290×10^6 and the gases to the boiler 270×10^6 B.T.U. or a difference of 20×10^6 B.T.U. The combustion air has, however, picked up about 33×10^6 B.T.U. before entering the checkers. There must, therefore, be an error in these items. The error is due to incorrect temperatures being used for the air to the checkers and the waste gases therefrom. Temperatures of gases, as recorded by pyrometers, are not correct, and cannot possibly be correct, as is so ably pointed out by Mr. Forster in his discussion of Mr. Clements' paper (See The Journal of the Iron and Steel Institute, Vol. No. 1, 1922, page 476). The radiation from the surrounding walls or brickwork influences the pyrometer readings, if the brickwork is of a different temperature than the gases passing the pyrometer. The temperature recorded is somewhere between the brickwork temperature and the gas temperature. Ordinary pyrometers surrounded by a refractory tube have also a lag in recording which must be taken into account. I have endeavored to illustrate this in Figure 1. The relations existing between recorded temperatures and the actual temperatures of the gases in open-hearth checkers are represented. Pyrometers, therefore, record too low a temperature for the gases giving up heat in the checkers and too high a temperature for gases taking up heat; or, in other words, the waste gases entering and leaving the checkers are higher in temperature than recorded and producer gas or air entering and leaving the checkers are lower than recorded. The exact calculation of the actual temperatures of the gases is difficult, because it is influenced by: (A) The average total temperature difference between the gases, or between the gases and the checkers. The larger

this is, the larger the difference is between the actual temperature of the gases and the recorded temperature. (B) The average ruling temperature of the checkers. The higher this temperature is, the larger the difference is between the actual temperature of the gases and the

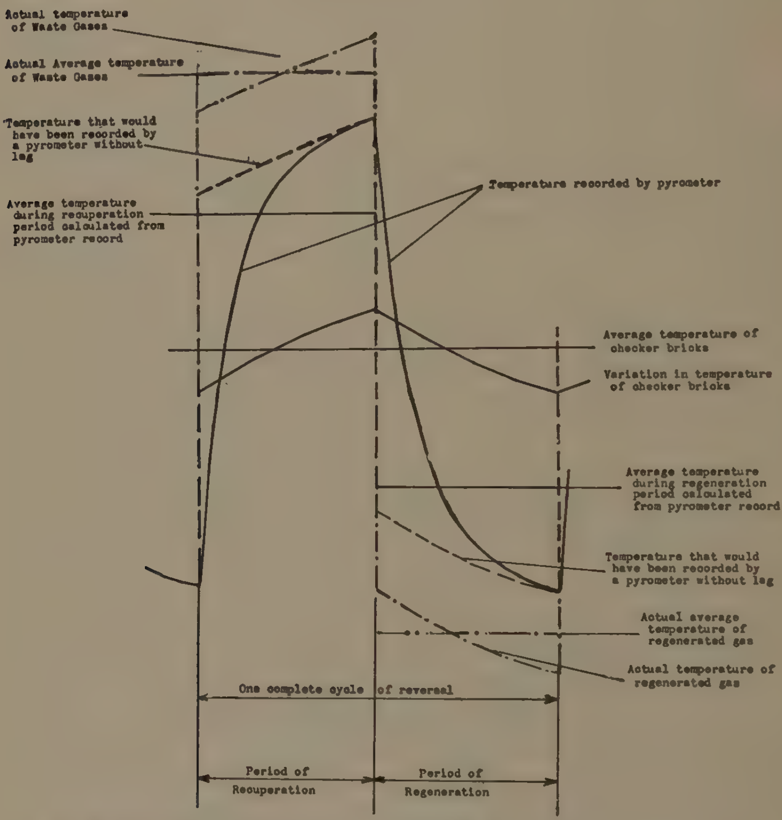

Fig. 1—Showing relation between actual and recorded temperatures in regenerative checker system.

recorded temperature, because the radiation increases rapidly with the temperature. (C) The velocity of the gases passing the pyrometer. The slower the velocity is, the larger the difference is between the actual temperature of the gases and the recorded temperature.

With this as a basis, a fairly good estimate can be

made of the actual temperature of the gases in the different parts of the regenerative system. The objection might be made that this is guesswork, and the only answer I can give to that is, that it is a guess in the right direction.

7.—A matter of great importance is also to find out how the waste gases are divided up between the gas and the air checkers. The calculations made by Mr. Clements from the temperatures of the gases in the checker-flues and in the common stack-flue are very uncertain and there are many causes of errors therein. A more reliable way is to calculate the heat taken up by the producer gas and the air in the checkers and calculate the total radiation loss from the checkers and distribute this loss properly between the checkers. From this can be obtained the heat left in the checkers by the gases in the different checkers, and the distribution of the waste gases can be calculated with due consideration to the temperatures of ingoing and outgoing gases. According to the calculations in the paper, the gas picked up $44.6\text{x}10^6$ B.T.U. in the checkers and the air $126.8\text{x}10^6$ B.T.U. The total radiation loss is given at $38.3\text{x}10^6$ B.T.U. If we assume that $13\text{x}10^6$ B.T.U. were radiated from the gas checkers we find that the waste gases have given up $57.6\text{x}10^6$ B.T.U. in the gas checkers and $152.1\text{x}10^6$ B.T.U. in the air checkers. If the temperature of the waste gases were the same, this would give a distribution of 27½% of the waste gases in the gas checkers.

8.—The observed temperatures of the hot pig iron and especially of the slags and the steel are from 150 to 200°F. too high. A higher specific heat for molten steel should also have been used, as pointed out by Dr. McCance and others in the discussion of Mr. Clements' paper.

9.—The heat in the steam from the waste heat boiler is calculated to be only 19.8% of the heat in the coal. I do not think that this does full justice to the waste heat boiler, as the monthly or yearly average for the whole plant is considerably above this, or about 23%, according

to figures which I have. It does not check up very well with the amount of waste gases given, if cooled down to 500°F. in the boiler.

10.—Consideration is not given to the producer gas which passes direct into the stack flue at each reversal. This gas can hardly be less than 3% of the total gas with 15-minute reversals.

11.—The specific heats of CH_4 and C_2H_4 are derived from Le Chatelier's figures per cubic meter, instead of per kilogram, and are not correct. The correct values per pound of these gases in B.T.U. are:

$$CH_4 = .58 + .000187\ T°F.$$
$$C_2H_4 = .40 + .000146\ T°F.$$

12.—The ultimate analysis of the coal on Fig. 4 is not the analysis of the coal as burned. The natural coal contains probably about 64% C. The amount of carbon gasified per pound of coal is about .61 pounds. If the analyses of the coal given are used for calculation of the amount of producer gas used, it will be much greater than shown.

In order to make my discussion of the chemical and the heat balance more clear, I have worked out the accompanying tables.

In Table A, I have attempted to construct a balance sheet for producer gas, by means of the analyses given in the paper. The first part is a distribution of the total gas to the furnace. Three per cent has been assumed to go direct into the stack flue. I have assumed the same amount of gas to the checkers as is given in the paper. The second part is a balance of gas in the checkers. A smaller quantity of air has entered into the checkers, which has reduced the heat value of the gas as shown by the analysis in the paper. The lowering of the total heat in the gas cannot be explained in any other way.

Table B is a complete melting chamber balance, including gases. Both balance of elements and of constituents are given. The latter is very useful, as it gives directly the increase or decrease in elements and compounds, as,

for instance, the increase in Fe and FeO. In order to make an accurate balance, the smallest possible changes have been made in the figures given in the paper. A slightly higher amount of metal tapped has been assumed to conform more closely with actual results in this plant. A loss of 2,021 pounds of Fe as Fe_2O_3 has been assumed. This loss is partly deposited in the slag pockets and checkers, and partly escapes into the stack. The heat carried by these losses has been neglected in my calculations.

Table C is a balance of waste gases on their way to the boiler. The producer gas which passed directly into the stack flue is also added. The amount of gases entering the boiler checks fairly well with the amount given in the paper. The increase of gases due to infiltration of air is about 27%.

From the quantities in these tables, Table D has been worked out. The temperatures given are worked out carefully from the temperature curves in the paper according to the ideas set forth in paragraph 6 above. Gross heat values have also been given, but not used in the calculations, for comparison with the figures in the paper. The temperature of the waste gases in the gas uptake is lower than in the air uptake according to the temperature records. The waste gases have been distributed between the gas and air checkers according to the ideas set forth in paragraph 7 above. The caloric heat has, however, been assumed to be equally divided. In a valuable paper by Mr. Witting, "Judging Fuels from Gas Analysis," published in the September, 1922, issue of The Association of Iron and Steel Electrical Engineers, page 517, it is pointed out that the waste gases to the gas checkers are higher in CO and lower in O_2 than to the air checkers, due to stratification in the melting chamber.

In Table E the heat from various chemical reactions is given. They check closely with the values in the paper, except for the reduction of Fe and FeO from Fe_2O_3, as set forth in paragraph 3 above. An item, consisting of

TABLE A—PRODUCER GAS BALANCE

		Weight, Pounds	Chemical Elements				Chemical Compounds and Free Elements						
			C	H	O	N	CO_2	CO	H	CH_4	C_2H_4	N	H_2O
Producer gas to checkers	Dry gas	209,500	27,600	2,850	43,670	135,380	31,400	36,500	1,820	3,670	730	135,380	....
	Moisture	18,000	....	2,000	16,000	....	....	....	....	....	....	....	18,000
Producer gas lost to stack in reversals	Dry gas	6,500	850	90	1,350	4,210	970	1,130	60	110	20	4,210	....
	Moisture	560	....	60	500	....	....	....	....	....	....	....	560
Producer gas to furnace. Total	Dry gas	216,000	28,450	2,940	45,020	139,590	32,370	37,630	1,880	3,780	750	139,590	....
	Moisture	18,560	....	2,060	16,500	....	....	....	....	....	....	....	18,560
Grand Total	....	234,560	28,450	5,000	61,520	139,590	32,370	37,630	1,880	3,780	750	139,590	18,560

PRODUCER GAS BALANCE IN CHECKERS

		Weight, Pounds	C	H	O	N	CO_2	CO	H	CH_4	C_2H_4	N	H_2O
Producer gas to checkers	Dry gas	209,500	27,600	2,850	43,670	135,380	31,400	36,500	1,820	3,670	730	135,380	....
	Moisture	18,000	....	2,000	16,000	....	....	....	....	....	....	....	18,000
Air	....	10,800	....	....	2,530	8,270	....	....	....	....	....	....	....
Producer gas to melting chamber	Dry gas	220,300	27,600	2,850	46,200	143,650	35,600	35,570	2,010	3,240	230	143,650	....
	Moisture	18,000	....	2,000	16,000	....	....	....	....	....	....	....	18,000
Grand Total	....	238,300	27,600	4,850	62,200	143,650	35,600	35,570	2,010	3,240	230	143,650	18,000

Table B.—CHEMICAL BALANCE OF THE MELTING CHAMBER

Chemical Elements and Stable Compounds

	Weight, Pounds	C	Si	P	Mn	S	Fe	CaO	MgO	Al_2O_3	CaF_2	O	H	N
[illegible]	114,000	4,902	1,083	251	1,607	36	106,121							
[illegible]	[illegible]	140		10	280	28	69,542							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	343	523	218		7,231	176	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	6,500	100	36		3,971	19	
[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	2,915	1,955	89		724	2	
[illegible]	[illegible]		[illegible]					[illegible]	[illegible]		[illegible]	[illegible]	4	
[illegible]	[illegible]		[illegible]			[illegible]						[illegible]		
[illegible]	[illegible]	[illegible]										[illegible]	[illegible]	[illegible]
[illegible]	[illegible]											[illegible]	2,000	
[illegible]	[illegible]											[illegible]		[illegible]
[illegible]	[illegible]											2,560	320	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]							
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		2,476		
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]						[illegible]				[illegible]	[illegible]		
[illegible]	[illegible]											[illegible]		[illegible]
[illegible]	[illegible]	[illegible]										[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Chemical Compounds and Free Elements

	CO_2	CO	H_2O	FeO	Fe_2O_3	SiO_2	MnO	P_2O_5	H	CH_4	C_2H_4	O	N	CaO, MgO [illegible]	C	Si	P	Mn	S	Fe
[illegible]															[illegible]	[illegible]	251	[illegible]	[illegible]	[illegible]
[illegible]															[illegible]		10	[illegible]	[illegible]	[illegible]
[illegible]	622		1,584	234	14,383	1,839	31	23						[illegible]						
[illegible]	5,215		169	31		41		3						[illegible]					[illegible]	
[illegible]	906		18	30		79								[illegible]					[illegible]	
[illegible]			[illegible]			9								780						
[illegible]						[illegible]													[illegible]	
[illegible]	[illegible]	[illegible]							[illegible]	[illegible]	[illegible]		[illegible]							
[illegible]			[illegible]																	
[illegible]												[illegible]	[illegible]							
[illegible]			2,880																	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]															[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						[illegible]					[illegible]	
[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						[illegible]					[illegible]	
[illegible]					[illegible]									[illegible]						
[illegible]	[illegible]	[illegible]										[illegible]	[illegible]							
[illegible]			[illegible]																	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

TABLE C.—BALANCE OF WASTE GASES IN CHECKERS

		Weight, Pounds	Chemical Elements				Chemical Compounds and Free Elements				
			C	O	H	N	CO_2	CO	H_2O	O	N
Waste gases	Dry gas	486,295	34,268	93,732	...	358,295	106,500	12,200	...	9,300	358,295
	Moisture	48,339	...	42,968	5,371	...	...	...	48,339	...	...
Air	Dry air	97,000	...	22,600	...	74,400	...	...	...	22,600	74,400
	Moisture	900	...	800	100	...	...	...	900	...	...
Total waste gases in checkers	Dry gas	583,295	34,268	116,332	...	432,695	116,700	5,700	...	28,200	432,695
	Moisture	49,239	...	43,768	5,471	...	...	...	49,239	...	...

BALANCE OF WASTE GASES BETWEEN CHECKERS AND WASTE HEAT BOILER

		Weight, Pounds	C	O	H	N	CO_2	CO	H_2O	O	N
Waste gases	Dry gas	583,295	34,268	116,332	...	432,695	116,700	5,700	...	28,200	432,695
	Moisture	49,239	...	43,768	5,471	...	...	...	49,239	...	...
Air	Dry air	46,500	...	10,866	...	35,634	...	...	...	...	...
	Moisture	450	...	400	50	...	...	...	...	...	...
Producer gas direct to boiler	Dry gas	6,500	850	1,350	90	4,210	...	...	...	...	...
	Moisture	560	...	500	60	...	...	...	...	...	...
Grand Total	...	686,544	35,118	173,216	5,671	472,539	...	...	...	...	...
Total waste gases to boiler	Dry gas	635,505	35,118	127,848	...	472,539	128,766	...	...	34,200	...
	Moisture	51,039	...	45,368	5,671	...	...	...	51,039	...	...

TABLE D—TEMPERATURES, QUANTITIES AND HEAT CONTENTS OF GASES IN THE FURNACE SYSTEM

	Item	Temperatures Degrees Fahrenheit	Quantities in pounds		Million B. T. U. above 62° F.		
			Dry	Moist	Calorific	Sensible	Total, based on net values
Producer gas to furnace	1	1,400	216,000	18,560	360.9 Net (388.9 Gross)	101.0	461.9
Producer gas direct to boiler	2	1,400	6,500	560	10.9 Net (11.7 Gross)	3.0	13.9
Producer gas to gas flue	3	1,400	209,500	18,000	350.0 Net (377.2 Gross)	98.0	448.0
Producer gas to checkers	4	1,090	220,300	18,000	350.0 Net (377.2 Gross)	76.2	426.2
Producer gas from checkers to melting chamber	5	1,700	220,300	18,000	336.4 Net	128.6	465.0
Air to checkers	6	400	230,000	2,300	....	19.0	19.0
Air from checkers to melting chamber	7	2,200	260,000	2,680	....	149.2	149.2
Waste gases to air checkers	8	2,540	364,725	36,259	26.8	317.0	343.8
Waste gases to gas checkers	9	2,250	121,570	12,080	26.8	90.7	117.5
Waste gases from air checkers	10	1,340	437,475	36,939	12.6	169.5	182.1
Waste gases from gas checkers	11	1,260	145,820	12,300	12.5	52.3	64.8
Waste gases from air valve	12	1,150	467,475	36,939	7.4	149.0	156.4
Waste gases from gas valve	13	1,200	155,820	12,300	7.8	52.2	60.0
Waste gases to boiler	14	1,260	635,505	51,039	....	227.3	227.3
Waste gases from boiler	15	500	675,505	51,439	....	81.8	81.8

The following heat values of combustion in B. T. U. per pound have been used in the calculations:

	Net	Gross
CO	4,400	4,400
H	52,508	62,028
CH_4	21,540	23,910
C_2H_4	20,200	21,550

TABLE E—HEAT DEVELOPED AND ABSORBED BY OXIDATION OF AND CHEMICAL REACTIONS OF ELEMENTS AND COMPOUNDS IN THE CHARGE AND SENSIBLE HEAT IN MATERIALS

	Item	Weight	Heat developed or absorbed in B. T. U. per pound	Temperature degrees Fahrenheit	Total heat produced or consumed, million B. T. U.
C in bath oxidized to CO_2	55	4,827 C	14,544 C	....	70.2
C in bath oxidized to CO only	56	4,827 C	4,324 C	....	20.9
Si to SiO_2	....	1,083 Si.	11,693 Si.	....	12.6
P to P_2O_5	....	247 P.	10,825 P.	....	2.7
Mn to MnO	....	1,547 Mn.	2,984 Mn.	....	4.6
Slag forming reactions: P_2O_5 to $Ca_3P_2O_5$	....	565 P_2O_5	2,020 P_2O_5	....	1.1
Slag forming reactions: SiO_2 to Ca_3SiO_5	....	2,571 SiO_2	860 SiO_2	....	2.2
Total heat developed by oxidation of Si, P and Mn and slag forming reactions	57	....	....	....	23.2
Fe reduced from Fe_2O_3	....	3,604 Fe.	3,240 Fe.	....	11.6
FeO reduced from Fe_2O_3	....	4,720 FeO	615 FeO	....	2.9
Total heat absorbed by the reduction of Fe and FeO from Fe_2O_3	58	....	....	....	14.5
Heat consumed in driving off CO_2 from Limestone, Dolomite, etc.	....	6,743 CO_2	1,850 CO_2	....	12.5
Heat consumed in vaporizing H_2O in charge	....	1,807 H_2O	1,057 H_2O	....	1.9
Total latent heat in CO_2 and H_2O driven off from charge	59	....	....	....	14.4
CO_2 from limestone reduced by metalloids in the charge to CO before escaping from the bath. Two-thirds of CO_2 is assumed to be broken up	60	3,470 CO_2 2,819 CO	4,400 CO	....	12.4
Sensible heat in CO_2 driven off from charge	....	6,743 CO_2	850	2,540	5.7
Sensible heat in H_2O driven off from charge	....	1,807 H_2O	1,710	2,540	3.1
Total sensible heat in CO_2 and H_2O driven off from charge	61	....	....	....	8.8
Sensible heat in pig iron	62	114,000	450	2,350	51.3
Sensible heat in steel tapped	63	179,890	610	2,900	109.6
Sensible heat in run-off slag	....	10,059	900	2,700	9.0
Sensible heat in tapping slag	....	16,306	960	2,900	15.6
Total sensible heat in slags	64	....	....	....	24.6
Sensible heat added to the charge, Items 63 + 64 − 62	65	....	....	....	82.9

TABLE F.—MISCELLANEOUS QUANTITIES OF HEAT

	Item	Million of B. T. U.
Heat in coal charged.... Gross, 11,445 B. T. U. per pound........	16	531.0
Heat in coal charged.... Net, 10,860 B. T. U. per pound........	17	504.0
Heat left in melting chamber and port ends by gases, Items 5 +7 − 8 − 9	18	152.9
Heat left in air checkers by waste gases, Items 8 − 10..............	19	161.7
Heat radiated from air checkers, Items 19 − (7 − 6)...............	20	31.5
Heat left in air flues and air valve by waste gases, Items 10 − 12....	21	25.7
Heat radiated from air flues and air valve, Items 21 − 6............	22	6.7
Heat left in gas checkers by waste gases, Items 9 − 11.............	23	52.7
Heat radiated from gas checkers, Items 23 − (5 − 4)...............	24	13.9
Heat left in gas flues and gas valves by waste gases, Items 11 − 13....	25	4.8
Heat left in gas header and gas valves by producer gas, Items 3 − 4.	26	21.8
Total heat left by waste gases and producer gas in gas flues, gas header and gas valve, Items 25 +26........................	27	26.6
Heat lost in cooling-water in gas valve.........................	28	10.8
Heat radiated from gas flues, gas header and gas valve, Items 27 − 28	29	15.8
Heat from waste gases and producer gas in flue to boiler, Items 12 + 13 + 2..	30	230.3
Heat left by waste gases in boiler flue and in cooling-water in stack damper, Items 30 − 14.................................	31	3.0
Heat lost to cooling-water in stack damper......................	32	1.2
Heat radiated from boiler flue, Items 31 − 32....................	33	1.8
Heat left by waste gases in boiler, Items 14 − 15..................	34	145.5
Heat radiated from boiler and boiler flues assumed................	35	15.0
Heat delivered to steam in boiler, Items 34 − 35..................	36	130.5
Heat in steam used for driving fan, 5% of total steam assumed.....	37	6.5
Heat in surplus steam from boiler, Items 36 − 37..................	38	124.0
Heat in steam used for blowing producers, 17,500 lbs. of about 1,100 B. T. U. delivered to steam in boiler......................	39	19.2
Heat in steam for other Departments than the Open-Hearth, Items 39 − 38..	40	104.8
Total heat developed by oxidizing all metalloids C to CO_2, Items 55 + 57..	41	93.4
Total heat absorbed by chemical reactions in the bath and sensible heat added to charge, Items 58 +59 +65....................	42	111.8
Heat supplied from producer gas fuel to charge, Items 42 − 41......	43	18.4
Total heat developed by oxidizing metalloids in the bath, C to CO only, Items 56 +57..	44	44.1
Total heat absorbed by chemical reactions in the bath, including the breaking up of part of CO_2 from limestone, sensible heat added to the charge and sensible heat in gases escaping from the bath, Items 42 +60 +61.....................................	45	133.0
Heat transferred to charge and bath from the gases in the melting chamber, Items 45 − 44..................................	46	88.9
Heat lost from the melting chamber and port ends, including heat to cooling-water, Items 18 − 43..............................	47	134.5
Heat to cooling-water in melting chamber and port ends...........	48	70.6
Actually radiated heat from melting chamber and port ends, Items 47 − 48..	49	63.9
Total actually radiated heat from all parts of the furnace system, Items 49 +20 +22 +24 +29 +33............................	50	133.6
Total heat lost in cooling-water, Items 28 +32 +48...............	51	82.6
Total radiated heat from the furnace system and heat to cooling-water, Items 50 +51, or Items 1 +42 − 41 − 14, or Items 1 − 43 − 14..	52	216.2

TABLE G.—EFFICIENCIES

		Items	Million of B. T. U. and Ratio	Efficiency, Per Cent
Gross efficiency of furnace (sensible heat added to charge in slags and steel and heat absorbed by chemical reactions in the bath, divided by total heat supplied by the fuel and the potential chemical heat in charge)....................	Based on net heat value in gas supplied to furnace...........	$\frac{42}{1+41}$	$\frac{111.8}{555.3}$	**20.9**
	Based on gross heat value of coal to producer..............	$\frac{42}{16+41}$	$\frac{111.8}{624.4}$	17.9
Net efficiency of furnace (heat supplied to the charge by the combustion of producer gas in the melting chamber, divided by heat supplied by the fuel)...........	Based on net heat value in the gas supplied to furnace.....	$\frac{43}{1}$	$\frac{18.4}{461.9}$	**4.0**
	Based on gross heat value of coal to producer..............	$\frac{43}{16}$	$\frac{18.4}{531.0}$	3.5
Bath efficiency (heat transferred from gases in the melting chamber to the charge and bath for accomplishing chemical reactions and for giving the necessary sensible heat to the slags and the steel and to the gaseous products from the reactions, divided by the fuel supplied.....................	Based on net heat in producer gas supplied to furnace.....	$\frac{46}{1}$	$\frac{88.9}{461.9}$	19.2
	Based on net heat in producer gas plus heat value of CO from charge........	$\frac{46}{1+(55-56)}$	$\frac{88.9}{511.2}$	**17.4**
Gross efficiency of air checkers (heat taken up by the air in the checkers only, divided by the heat left in the air checkers by the waste gases)..............................		$\frac{7-6}{19}$	$\frac{130.2}{161.7}$	80.5
Gross efficiency of air checkers, flues and air valve (total heat taken up by the air, divided by heat left by waste gases in these parts)................................		$\frac{7}{19+21}$	$\frac{149.2}{187.4}$	79.6
Net efficiency of air checkers, air flues and air valve (total heat taken up by the air, divided by the heat in waste gases entering the air checkers)......................		$\frac{7}{8}$	$\frac{149.2}{343.8}$	43.4
Gross efficiency of gas checkers (heat taken up by the air in the gas checkers only, divided by the heat left in the gas checkers by the waste gases).........................		$\frac{5-4}{23}$	$\frac{38.8}{52.7}$	73.6
Gross efficiency of gas checkers, flues and gas valve (heat taken up by the producer gas, supplied to the melting chamber, divided by the total heat left by the waste gases in these parts)....................................		$\frac{5-3}{23+25}$	$\frac{17.0}{57.5}$	29.6
Net efficiency of gas checkers, flues and gas valve (difference in the heat in gas to the melting chamber and the heat in total gas to the furnace, including gas lost due to reversals, divided by the heat in the waste gases entering the gas checkers)..		$\frac{5-1}{9}$	$\frac{3.1}{117.5}$	2.6
Gross efficiency of boiler (heat in the steam after subtracting the heat in steam for driving fan, divided by the heat in the waste gases to the boiler)..................		$\frac{38}{14}$	$\frac{124.0}{227.3}$	54.6
Net efficiency of boiler (heat in the steam after subtracting the heat in steam for driving fan, divided by total heat in fuel)......	Based on net heat in producer gas.......	$\frac{38}{1}$	$\frac{124.0}{461.9}$	26.9
	Based on gross heat in coal..............	$\frac{38}{16}$	$\frac{124.0}{531.0}$	23.4
Net efficiency of boiler based on steam available for other departments (heat in the steam after subtracting heat in steam for driving fan and heat for blowing producers, divided by total heat in the fuel.....................	Based on net heat in producer gas.......	$\frac{40}{1}$	$\frac{104.8}{461,9}$	22.7
	Based on gross heat in coal................	$\frac{40}{16}$	$\frac{104.8}{531.0}$	19.8

the breaking up of CO_2 from limestone, has been added in accordance with paragraph 4.

The heat quantities in Table F are calculated from the different items in Tables D and E. In this table most heat items of interest are given. The radiation from the melting chamber and port ends is 63.9×10^6 B.T.U. instead of 17.5×10^6 B.T.U. in the paper, as set forth in paragraph 1. From these heat items the efficiencies of the furnace as a whole or of any of its parts can be calculated. This has been done in Table G. The three most representative furnace efficiencies are in bold type. These are called Gross, Net and Bath Efficiencies. All three are representative of the work done by the furnace, and in comparing the work of one furnace with another, all three should be calculated on an equal basis. A net efficiency of only 4% may at first seem incompatible with a bath efficiency of 17.4%. This means simply that part of the heat absorbed by the charge or bath from the gases in the melting chamber has been derived from the combustion of gases from the bath itself and that part of the heat radiated from the furnace or sensible heat in the waste gases is also derived from this source. The fact is that the total heat losses from the furnace represent 96% of the total heat in the producer gas to the furnace. In Mr. Clements' furnace, these losses represent about 92%. In order to make this more clear a general heat balance has been prepared in Table H.

The three different efficiencies are, of course, the average for the heat and they vary very much during the heat. This is especially so with the net efficiency. Mr. Clements has made a most admirable effort to make a heat balance during thirty minutes of working the heat. This balance shows that the total heat in the producer gas was insufficient to cover the total heat losses. This means, of course, that the net efficiency is less than zero, and that the heat in the furnace system was maintained partly by reactions in the bath or the combustion of gases therefrom. This is a very interesting fact indeed. On the

other hand, it is evident that towards the end of the heat, when practically all chemical reactions have stopped, the net efficiency must be much higher than 4%, otherwise it would take a very long time to raise the temperature of the bath. At the beginning of the heat the net efficiency must also be high. If the pig iron in our heat had been charged cold, it would be required to add 51.3x10⁶ B.T.U. more to the charge. If the efficiency was only 4% it would require 1,280x10⁶ additional B.T.U. in the gas or nearly four times more gas than used for our heat. The fact is,

TABLE H.—GENERAL HEAT BALANCE

			Million of B. T. U.
Total heat in producer gas to furnace, based on net heat values, Item No. 1....			461.9
Total heat from chemical reactions in the charge, Items 55 +57..............			93.4
Total heat input..			555.3
Total sensible heat added to charge in steel and slags and heat absorbed by chemical reactions in the bath..........	Chemical reactions, Items 58, 59...	28.9	111.8
	Sensible heat added to charge, Item 65..........................	82.9	
Heat in waste gases to boiler, Item No. 14..................................			227.3
Heat abstracted by cooling-water from.......................	Melting chamber, Item No. 48....	70.6	82.6
	Gas valve, Item No. 28...........	10.8	
	Stack damper, Item No. 32.......	1.2	
Radiated heat, from furnace.....	From melting chamber and port ends, Item No. 49..............	63.9	133.6
	From checkers, slag pockets and flues, Items 20, 22, 24, 29, 33....	69.7	
Total heat output..			555.3

however, that the net efficiency for melting this pig iron is about 35% to 40% and would require about 140x10⁶ additional B.T.U., or about 30% more fuel. I have endeavored to represent the variations of the various efficiencies during a heat as curves in Figure 2. The net efficiency drops below the zero line during part of the heat, when the chemical reactions and the boil are at the highest point. At the beginning of the cold charge heat and at the end of the heats, the three curves come together, as is natural, since there are practically no chemical reactions during these stages. The average efficiencies for the cold charge heat

are simply derived from the other efficiencies by adding to the heat items above the line 51.3 and below the line 140, the former representing the heat required to melt the pig and the latter the additional heat in the gas required to accomplish this.

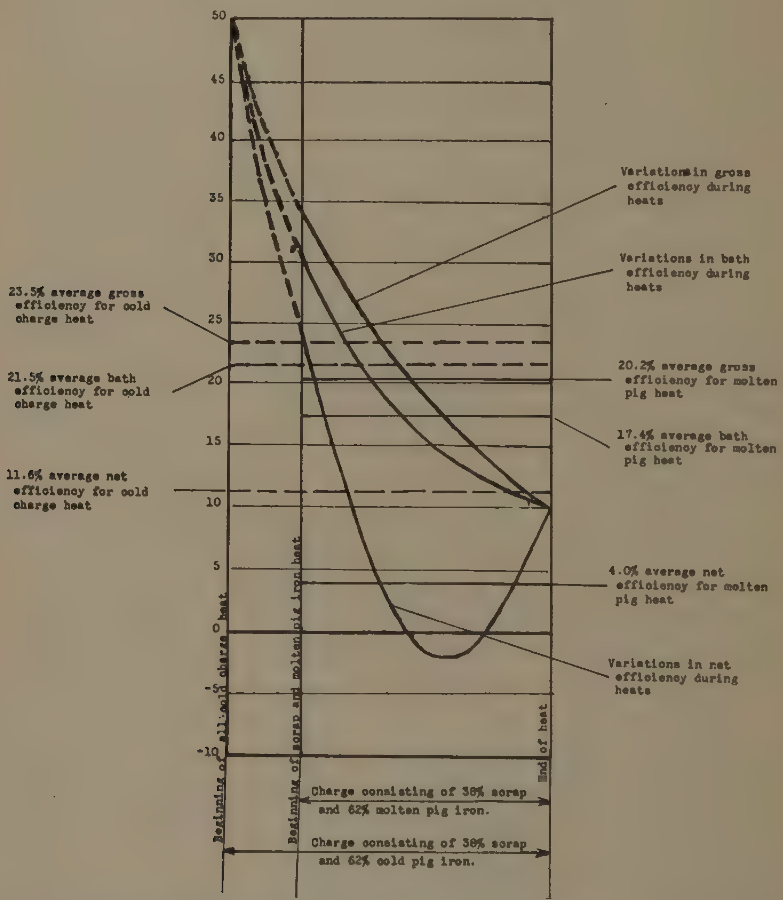

Fig. 2—Showing variations in efficiencies of the open-hearth furnace during the heats.

A most remarkable fact that the heat balance teaches us is, however, that of the 461.3x10⁶ B.T.U. contained in the waste gases from the port ends, only 166.3x10⁶ B.T.U., or about 36%, are recovered in preheating the gas and

air. It is not possible to recover very much more heat from the waste gases, because the capacity of the incoming gas and air to take up heat is limited, and even if the checkers were one hundred times larger no more heat could be recovered from the waste gases in the producer gas and air; and the waste gases would have exactly the same temperature if the radiated heat and the infiltration of air were the same. Low stack temperature does not mean that the furnace is more efficient. It simply means that the checkers are badly insulated and large amounts of air infiltrate. It has sometimes been noticed that, when a change has been made in the burners or ports so that the furnace works better with less fuel consumption, the stack temperature drops off. This is due to the fact that the same radiation heat is withdrawn from a smaller quantity of waste gases and that the air infiltrated mixes with a smaller amount of waste gases, and the stack temperature is lowered from both these causes. However, if the checkers were better insulated and tighter, the stack temperature would go up perhaps much higher than before the change and the furnace would do still better work. Under equal conditions of combustion in the melting chamber, it can be stated that the furnace with the highest stack temperature is working more efficiently. This fact favors the use of waste heat boilers.

Table I has been prepared to show possible gain in steam output by reducing some of the present losses. The percentage of savings in the different items are reasonable, but the large increase in steam output resulting therefrom is rather surprising.

The heat conditions in the gas checkers are worthy of closer study. The net increase in heat in the gas between the header and the uptake is only 3.1×10^6 B.T.U. or about one-half of 1% of the total heat available in the gas and air in the melting chamber. Practically no gain has therefore been derived from passing the gas through the checkers. It is doubtful if there is any gain at all, and perhaps there is an actual loss, because after leaving the

point in the uptake where the temperature is taken, the gas loses sensible heat in passing over numerous water-cooling pipes before reaching the combustion chamber. The reason for the low temperature attained by the gas in the uptake is that a relatively small amount of waste gases passes into the gas checkers and these gases are cooled down considerably by water-cooling pipes even before they reach the slag pocket. If there were means to divert a greater amount of the waste gases to the gas

TABLE I.—POSSIBLE GAIN IN OUTPUT OF STEAM IF THE FOLLOWING SAVINGS IN HEAT LOSSES COULD BE ACCOMPLISHED

		Saving of Heat, Per Cent	Saving of Heat, in Million B. T. U.
Heat in the cooling-water	To melting chamber, Item No. 48	30	21.2
	To gas valve, Item No. 28	80	8.6
	To stack damper, Item No. 32	None	None
Radiated heat from furnace	From melting chamber and port ends, Item 49	None	None
	From checkers and flues, Item 50 — 49	50	34.8
50% less infiltration of air between melting chamber and boiler outlet results in a saving of		14% of heat in gases leaving boiler.	11.5
Total saving of heat available for waste heat boiler		....	76.1
Heat in surplus steam at present produced, Item No. 38		....	124.0
Increase of steam due to reduced heat losses		....	61.3%
Net efficiency of boiler (heat in steam after subtracting the heat in steam for driving fan, divided by total heat in producer gas)		At present	26.9%
		With possible savings in heat losses from furnace	43.3%

checker, or if less water-cooling were used in the gas port and uptake, more could be gained.

The conditions stated above, however, bring up the old question of passing the hot producer gas direct into the melting chamber instead of through checkers. The successful operation of, and the rather remarkable results obtained in, the South Chicago furnace under the heat conditions just mentioned, and with a very poor gas, constitute in my opinion one of the strongest arguments for passing the gas direct to the melting chamber. Well insulated gas flues and dry shut-off valves close to the

port ends would be required in order to maintain the temperature of the gas at 1400°F. at the ports. The gas ports would be much smaller than those at present used and water-cooling of the inside of the ports would not be necessary. Nearly all heat losses of the gas regenerative system and part of the cooling-water heat losses also could be recovered in the waste heat boiler. The first mentioned heat losses amount to 40.5×10^6 B.T.U. or 8.7% of the total heat in the producer gas fuel.

It has also been proposed to pass part of the waste gases direct from the melting chamber to a waste heat boiler, because only about one-half of the total amount of waste gases are actually required for giving the necessary heat to the air checkers for preheating the air. There are ways to divert the other half of the gases to a boiler without using valves and without large heat losses. The waste gases from the air checkers would in such case be cooled down to about 500°F. and would pass direct to the stack. The waste heat boiler would operate with temperatures common in ordinary boiler installations and would run at a 150% to 200% rating. The boiler would be of relatively small dimensions and a smaller fan would be required. The amount of slag in the slag pockets and deposits in the air checkers would also be reduced correspondingly. It seems to me that this proposition has several advantages.

The papers by Kinney and McDermott and by Clements mentioned in this discussion have brought out many new points of interest and it may be hoped that they will encourage open-hearth men to investigate the conditions in other instances under different operating conditions.

VICE-PRESIDENT TOPPING: The next paper is the last on the program, Fluorspar and Its Uses, by Mr. G. H. Jones, president, Hillside Fluor Spar Mines, Chicago, Ill.

FLUORSPAR AND ITS USES

G. H. Jones

President, Hillside Fluor Spar Mines, Chicago, Ill.

Fluorspar, a comparatively unknown non-metallic mineral of moderate cost, widely distributed geologically, but of commercial value only in a few places in the world, is of essential and economic importance to steel makers from the fact that 80 to 85 per cent of the world's production is used in basic open-hearth and electric furnaces as a flux and detergent, and there is no known substitute.

Fluorite, as it is technically known and chemically as calcium fluoride (CaF_2), consists of calcium and fluorine in the proportions of 51.1 and 48.9 respectively. It is of a glassy luster and is only slightly harder than calcite and may be scratched with a knife. It crushes easily and may be distinguished from calcite by its failure to effervesce with dilute hydrochloric acid. It crystallizes in the isometric system and is often found in cubical crystals. Its specific gravity is 3.2 and it weighs approximately 200 pounds per cubic foot. Its cleavage is perfect. Its melting point is about 1650° F. In color fluorspar ranges, according to purity, from a clear colorless to a slightly bluish glass-like substance through various brilliant shades, and much of it is quite opaque. The color has little significance chemically.

The deposits thus far exploited in the United States are in Arizona, Colorado, Illinois, Kentucky, New Hampshire, New Mexico, Tennessee and Utah. Dependable domestic production based upon existing market conditions can only be obtained by users east of the Missouri River, from the Illinois-Kentucky districts, the great size and purity of which indicate that for many years they will continue to be the main source of our supply.

The tonnage may be divided between Illinois and Kentucky as 70 is to 30.

In England fluorspar occurs abundantly in the carboniferous limestone and associated shale of the Yoredale group, where it is found as the gangue of metalliferous veins. It is usually but not invariably associated with calcite, quartz and barytes. The principal producing localities are in Durham and Derbyshire. A large proportion of the fluorspar produced in England has been obtained by screenings from waste dumps from old lead mines. But in the last few years the demand has called for a greater production. Other sources, including mining, are helping to furnish an adequate domestic supply and some tonnage for export.

In Canada there are known deposits in Ontario, but they are negligible from a commercial standpoint and worthy only of passing notice. Some fluorspar is mined near Trail in British Columbia, but now finds a possible market among steel makers only on the Pacific Coast.

Germany has been an exporter for some years of high grade ground fluorspar, and is now prepared to furnish gravel for steel making from several mines, which have been opened under the stimulus of increased domestic demand and the possibility of exporting to the United States and other countries.

In Mexico, fluorspar has been found in many places but has been mined commercially in only one, a large deposit located near Guadalcazar, in San Luis Potosi. Other deposits promise to become profitable, and one of green fluorite, in Zacatecas, has been worked to a small extent.

In the United States buyers of fluorspar in Colorado, Utah and the Pacific Coast will continue to secure their supply from the western and foreign producers, as the rates of freight from the Illinois-Kentucky fields are too high for successful competition.

Fluorspar, formerly largely a waste product of the gangue of lead mines and in a smaller amount of other

metal mines, was used in smelting as long ago as 1529 (Agricola), and according to H. Foster Bain, fluorspar was first discovered in place in Illinois in 1839, when it was encountered in galena in sinking a well on the farm now the property of the Fairview Company. In 1842 spar was discovered in galena near the site of the present Rosiclare mine. From that time on mining appears to have been carried on more or less continuously, but shipments did not begin until the early seventies and since 1880 have been regularly reported. In 1891 only one or two mines were actually making shipments. The production of washed gravel spar commenced in the spring of 1894, although the demand for it by steel companies at that time was small. A limited tonnage of lump spar was produced and shipped four or five years earlier.

Its consumption runs evenly with the production of basic open-hearth steel ingots, and its production increases or decreases as the steel business is good or bad.

The demand for steel making is for a washed gravel, sized ¾-inch and under, of 85 per cent and over in calcium fluoride and not to exceed 5 per cent in silica, and free from sulphides, lead and zinc, the shipper being penalized according to an agreed percentage, varying with different buyers, for a lower calcium fluoride or a higher silica content than the percentages here given.

A properly equipped mine has its own laboratory and watches the analyses as they are made from the mill feed, mill run and car loadings, and is therefore in a position to guarantee the user the analysis specified.

This brings to my mind the necessity for buyers to adopt standard specifications for fluorspar and I suggest that this be taken up with the American Society for Testing Materials in order to determine what analysis is best for steel makers and other users, presenting penalties for inferior quality, and a bonus for superior ones, as in the case of iron ore, bearing in mind that the

analysis specified should be fair and reasonable and not increase the cost to the seller, or make it so difficult to produce as to lessen the supply.

The open-hearth melter would then know exactly what he had to work with. It is a common assumption that the melter throws in so much spar whether high or low in calcium fluoride or silica, but that is not the case as he uses only enough to bring about the reaction required, and in that way readily determines the grade employed. There should be no excuse for paying for, and paying freight on unnecessary impurities, and the value of fluorspar to the steel maker should be based upon the amount of calcium fluoride and the lack of silica at consumers' bins.

Calcite which practically represents the difference between calcium fluoride and silica and 100 per cent is lime, and therefore not injurious, but of some value in the furnace.

The modern fluorspar concentrating mills eliminate all impurities objectionable to the users such as lead, zinc and barium sulphides, and these impurities have only to be considered when buying foreign fluorspar, or that shipped from mines having no separating equipment.

From the heads of the operating departments of a large steel company, I have been given the following information:

The elimination of phosphorus and sulphur depends almost entirely upon the limestone, so in order to take care of the phosphorus and sulphur it is necessary at all times to have a highly basic fluid slag. Phosphorus is reduced at a low temperature while sulphur is reduced at a high temperature. In fact, most of the sulphur is reduced after the heat has been melted and the slag made fluid and the bath raised to higher temperature.

The limestone slag, immediately after the heat is melted, lies like a blanket upon the bath and to insure proper oxidizing conditions it is necessary to thin up the slag, and render it more fluid so that the metallic

contents of the bath will come into more intimate contact with the oxidizing slag. It is the universal practice in this country to use fluorspar for this purpose. Fluorspar acts as a neutral reagent and does not affect the basicity of the slag. The increased fluidity not only allows for quicker elimination of impurities in the metal but allows the transference of heat from the fuel to the bath of metal in much quicker time.

Twenty years or more ago it was the general practice in most of the steel plants of this country to add fluorspar just before the furnace was ready for tapping. During later years, however, it has become the more general practice to add the fluorspar in the early stages of the working of the heat, not only to allow the slag time enough to function properly with regard to impurities in the metal, but to eliminate sulphur at higher temperature and to allow the furnaceman more opportunity to quickly raise the temperature of the bath in case it is necessary to tap the heat a little early.

In some steel making districts, particularly in the east, pig iron is apt to be high in phosphorus and low in manganese and it is the general practice where scrap is plentiful and cheap, to charge as little pig iron as possible. Iron of this character requires a high lime charge, due to the fact that the small pig iron charge with consequent decreased amount of silicon and manganese does not tend to create a fluid slag: therefore, large additions of fluorspar are necessary. High manganese pig iron increases the fluidity of the slag and, therefore, decreases the amount of fluorspar necessary for thinning out the slag. A low silica content in fluorspar is most desirable as a high silica content means additional limestone. The latter item is not desirable from a tonnage standpoint because a high limestone charge adds to the time of heat in the furnace with the subsequent reduction of tonnage.

The general practice in this country would indicate the average consumption of from eight to ten pounds of

fluorspar per ton of steel. This depends upon the character of pig iron, scrap, etc., used in the various districts. The use of alumina as a substitute for fluorspar is being advocated in some quarters but to date has not been proved up commercially.

No bad effects of the spar on the walls or roof of the open-hearth furnace have been known and it has been found as time goes on that open-hearth superintendents are increasing the amount of flourspar used per ton of steel melted.

Mr. H. M. Howe in "The Metallurgy of Steel" (1890) in summing up fluorspar says it appears to favor dephosphorization:

1. By liquefying the slag and enabling it to assimilate the lime present, part of which might otherwise remain unmolten and inert and thus rendering the slag effectively basic to it.

2. Probably by volatilizing silicon from the metal, thus diminishing the formation of silica and thereby increasing the basicity of the slag.

3. In certain cases, for example, when the conditions are not strongly oxidizing, by volatilizing phosphorus as fluoride.

Dr. Richard Moldenke at the New York Institute meeting, February 19, 1922, claimed that basic hearth electric furnaces should be used in every new installation. To desulphurize rapidly and well, lime and fluorspar must be used in combination to form an active slag on the molten metal.

The Iron Age, April 6, 1922, under the heading of "Fluorspar in the Open-Hearth" reviews editorially an article from a German source previously printed in The Iron Age of March 23, 1922, to which I refer you, as follows:

"New light is thrown on the chemistry of basic open-hearth practice by an article from a German source in The Iron Age of March 23 on 'Fluorspar in Open-Hearth Practice.' It is important to American steel makers in

view of the large tonnage of basic open-hearth steel made in this country. Fluorspar is used in almost every heat of such steel, but the common thinking as to its function has not gone beyond the thinning of the slag and the cutting of the lime.

"The German studies show that fluorspar does more than this. It is an effective agent, when properly used, in removing sulphur from the steel. Comparing nine heats without fluorspar and nine in which it was used, the writer shows that in the first set, with all other conditions the same, the average sulphur content of the finished steel was 0.08 per cent and in the second set sulphur was down to 0.05 per cent. The author controverts the theory that the desulphurization, when fluorspar is used, is brought about by the slag being thus rendered more basic, and he shows by actual results that the ratio of the oxygen of the bases to that of the acids was 1.67 without fluorspar and 1.30 when fluorspar was used, there being in the latter case a marked decrease in sulphur in the steel. The presence of too much sulphur in basic steel has been a matter of no small concern in this country, it being more difficult to remove this element than to remove phosphorus in basic practice."

Outside of the steel industry many uses, and growing ones, are found for fluorspar. The glass, ceramic and enameling trades, including enameled tile and brick, are the next largest users, and use the highest grade hand picked and ground spar. Then come perhaps the electrolytical smelting of lead and antimony and other nonferrous and ferrous smelters. It is also commencing to regain the standing it once had among foundries, the demand from which is expected to steadily increase, as the benefits derived include the reduction of the coke necessary on account of the reduction of the number of pounds of fluxing material used. Cleaner castings are obtained on account of more fluid metal and greater freedom from slag, and stronger castings for the same reason. Less iron is lost in the slag and the slag is more

liquid. Less work is required in cleaning and repairing the cupola and taking care of the dump, by reason of the liquid slag causing the cupola to clean itself more readily, and that this class of slag is brittle and hence breaks up more readily in cleaning away the dump.

Fluorspar is also the main component part of many special foundry fluxes. It is used in the manufacture of carbide; in the preparation of a cyanide for the extraction of gold; in the mixing of certain cement waterproofing compounds; in a limited way by some Portland cement manufacturers; by chemical works in the manufacture of hydrofluoric acid, and sodium fluoride, practically chemically pure spar being specified. Also in the extraction of aluminum from bauxite.

A word about sodium fluoride for preserving wood. Mr. George M. Hunt in charge of section of Wood Preservative Forest Products Laboratory of the United States Government writes: "The desirability of sodium fluoride as a wood preservative is practically established. One large coal mining company has been using sodium fluoride since 1915 for the treatment of its mine timbers in preference to either coal tar, creosote or zinc chloride.

The present consumption of zinc chloride for wood preservation is about 25,000 tons per year, and the use of creosote is somewhat in excess of this.

Sodium fluoride can be used in the same manner with the same apparatus and for the same wood preserving purposes as zinc chloride. Sodium fluoride is twice as toxic as zinc chloride, is much less corrosive, does not injure paint, can be shipped as a dry powder in slack cooperage, and if it were in adequate supply at a reasonable price would eventually largely supersede zinc chloride, and probably creosote to a great extent.

Wood treated with sodium fluoride is non-inflammable, hard to ignite, burning poorly, and easily extinguished. This is practically the same as with zinc chloride, whereas creosote burns freely with a black smoke.

Several European countries and especially Austria, are making extensive use of sodium fluoride in preservation of all kinds of wood work, such as warehouses, dwellings and other building construction. It is also used more or less as an insecticide.

Mr. Benedict Crowell in the Engineering and Mining Journal, January 21, 1922, made the statement which follows: It is not generally realized that the known fluorspar deposits of this country are very limited in extent. War stimulation failed to develop a single new ore body of consequence, that I know of. The increased supply in 1917 and 1918 came from the exhaustion of reserves at the principal mines, depletion of all old and newly located shallow deposits, working over old dumps, and salvaging the low grade ore left in the old workings of abandoned mines. Prices of $35 to $60 per ton justified extreme activity.

Only four producers in the Illinois-Kentucky district have railroad connections. The rest are compelled to haul the ore and supplies from four to fifteen miles over dirt roads, that are almost impassable for five months of the year.

During the war period many new companies were organized to develop and operate fluorspar prospects. Practically all used up their capital and passed into history. Many of them never actually produced a car of ore.

Exhaustion of shallow deposits, the uncertainty and added cost of deeper mining, necessary exploration, and dead work are contributing factors which have tripled the cost of producing fluorspar. It has become a complicated, expensive and relatively deep mining proposition.

Mr. J. M. Blayney, president of the Fairview Fluorspar and Lead Company in The Iron Trade Review, February 9, 1922, says: "The fluorspar industry today bears little resemblance to that existing six years ago. Few branches of business have so changed in such a

short span of years, and probably in no other does the consumer know so little about the source of supply.

"In the earlier years the smaller demand was easily satisfied principally by a few operators favorably located on the Rosiclare vein in Hardin county who were mining comparatively large bodies at shallow levels and at low cost. In those days the shaft was small, the equipment was crude, and the milling plants were easily and inexpensively constructed. The ore bodies were relatively wide and the ore was of good quality, carrying little waste. The milling methods were simple and labor was cheap.

"Of all the operations in the Kentucky field, only one producing mine has a railroad connection. Most of the others lie from three to fourteen miles from the shipping point, and the mine product and supplies must be hauled by team over dirt roads wholly impassable for such use about five months of each year.

"It is the consensus of opinion of mining engineers familiar with the industry that fluorspar deposits cannot be determined with any reasonable assurance except by the sinking of shafts and the driving of drifts. Diamond drilling is practically useless for the purpose of blocking out ore bodies. This is due, first, to the frequent pinches, both lateral and perpendicular, and to the rapidly changing widths and erratic character of the deposits themselves. In the second place, the Rosiclare district is largely honeycombed with narrow fissures or slips containing fluorspar from a few inches to a foot in width, lying at various angles and wholly unconnected with any commercial deposits of fluorspar, rendering the reading of core results uncertain. Diamond drilling has been tried for many years in the district by half a dozen different companies, but no commercial body of fluorspar has ever been developed by its use. Expensive shafts have been sunk on the apparent indications of diamond drill cores and in each case have failed to develop ore bodies."

Production of fluorspar in the United States was first reported in 1883. Years of normal production are:

1883	4,000 tons
1892	12,250 tons
1900	18,450 tons
1905	57,385 tons
1910	69,427 tons
1915	136,941 tons
1920	186,778 tons

The largest shipments, due to previous war demands, were 263,817 tons in 1918 to which add 12,572 tons imported in that year.

In 1921 shipments dropped to 34,960 tons due to large stocks and depression in the steel business.

English production has averaged for the last eight years about 50,000 tons annually. Exact German production reports are not available, but indicate about 8,000 tons annually, and should show much larger for 1921 and 1922.

The highest average prices realized for fluorspar at mines including shipments made on old low-price contracts were:

1918	$20.72 per ton
1919	25.49 per ton
1920	25.26 per ton

Basic open-hearth steel production at five-year intervals shows:

1900	2,545,091 tons
1905	7,815,728 tons
1910	15,292,329 tons
1915	22,308,725 tons
1920	31,375,723 tons

As indicating the consumption of fluorspar for these years gravel fluorspar was produced in the United States as follows:

1910	52,013 tons
1915	114,151 tons
1920	154,786 tons

No records were kept of importations when fluorspar was on the free list, prior to August 1909, but for subsequent years imports were as follows:

1910	42,488 tons (largest on record)
1915	7,167 tons
1920	24,612 tons

Of the 1920 imports England furnished 17,096 tons, Canada, 7,086 tons, chiefly from British Columbia, and Germany, 407 tons.

Fluorspar was on the free list until August, 1909, when a duty of \$3.00 per ton went into effect. This was reduced to \$1.50 per ton, October, 1913. The present duty of \$5.60 per ton is in the new tariff of September, 1922.

Shipments are made in open or box cars, in bulk or in 125-pound bags or barrels, and in less than carloads in these packages.

A rough estimate shows consumption about as follows:

Steel ingots and castings	80 to 85%
Glass and enameling	7½ to 10%
Hydrofluoric acid	5 to 6%
Foundries	1 to 2%
Miscellaneous	2%

Geological Features

The Illinois State Geological Survey (Bulletin No. 41, 1920) in cooperation with the United States Geological Survey has made a careful study of the geology of the fluorspar region in Illinois and has issued a very interesting and complete report covering its field work.

The rock formation consists of limestone, shales and sandstones of Devonian, Mississipian and Pennsylvanian age with massive limestone beds predominating, the uppermost series of these beds underlying the coal measures, dipping under them to the north and west.

Structurally the geology is very interesting as the rock beds have been bowed up to form an immense dome. The intrusion of igneous dikes and sills caused further rock movements and adjustments with differential settings of large blocks and the formation of large fissures and faults. These faults, planes and fissures furnished channels in which ore-bearing solutions traversed the strata and where conditions were favorable filled up the fissures with ore deposits containing fluorite,

lead and zinc, with a calcite gangue. Not all fissures contain ore nor are all ore deposits in fissures, but it seems well established that the ore-bearing solutions used the fissures as channels for circulation.

The amount of movement along the faults has been considerable, and in some cases a vertical displacement of as much as 1500 feet has been noted.

Due to successive adjustments along some of these

Fig. 1—Buildings and surface equipment of Hillside Mine, Rosiclare, Ill.

larger faults, extensive shear zones are common and minor or relief faults often occur at some distance from the main fault fissures, and sometimes these lesser fissures contain important ore bodies.

The first mineral to be deposited in the fissures was calcite, and later changes in the character of the circulating waters and often a further series of rock movements caused the calcite to be redissolved and replaced by fluorite accompanied by lead and sometimes zinc.

As is often the case in many mining districts, there

is in the Illinois fluorspar district, one especially notable vein or fissure system. This unusual vertical fissure vein is known as the Rosiclare vein which, with several parallel veins formed at the same time, has produced nearly all the fluorspar mined in Illinois. This vein has been traced for a length of nearly three miles and the underground workings on it total some 10,000 feet in length and it has been developed to a depth of 620 feet from the surface. The dip of this vein is to the west, but it is so slight as to be practically vertical.

The ore chutes on this fissure attain a maximum known width of about 22 feet with an average width of 6 to 8 feet. There are narrow spots or pinches alternating with good sized bodies of ore, as is usual in most fissure veins, and some ore chutes have been mined that measured over 1,000 feet long.

There is one fluorspar deposit, located near Cave-in-Rock, Illinois, which is unusual in that the fluorite has replaced a bed of limestone. Apparently the mineral-bearing waters circulated through the fissure which was closed by a bed of shale overlying a soft permeable limestone which has been replaced by fluorspar. In places this deposit is workable and several mining operations have been conducted on this bed which outcrops on the side of a hill, making open cut work feasible for moderate distances followed by underground mining from adits.

Three companies operate on the Rosiclare vein, namely the Rosiclare Lead and Fluor Spar Mining Company, The Fairview Fluorspar and Lead Company, and the Hillside Fluor Spar Mines.

Mining Methods

The usual methods of developing the fluorspar deposits in the fissure veins is by means of vertical shafts and drifts in the ore at vertical intervals of 75 to 100 feet. The larger mines put down a three-compartment con-

creted shaft with two compartments for cages or skips and a pipe and ladder compartment. The dimensions vary according to the standards of different operators, but a typical shaft would be about 15 feet long by 5 feet 6 inches wide inside the timbers.

Present day practice is to construct the collar of working shafts, of concrete and to use wood or steel for dividers and wood guides. As the limestone stands very well

Fig. 2—Drilling the vein on the 350-foot level, Hillside Mine, Rosiclare, Ill.

it is not usually considered necessary to timber closely and regular timber sets are not used in solid ground, the dividers to carry guides, etc., merely being set into hitches cut in the rock.

When in ore it is customary to drive the drifts the full width of the ore and 12 to 14 feet high so that the necessary head room for setting timbers is secured.

Hitches are cut in the foot wall and heavy stulls are set across to the hanging wall, spaced about six-feet centers, the head of the stull being several feet higher

than the foot, depending upon the width of the drift. These stulls are usually set with the heel or hitch end about five feet above the tram tracks and chutes for drawing ore are then built between alternate pairs of stulls.

The stulls are then covered with poles or split lagging and stoping begins by shooting down the ore upon the timbers and drawing it off through chutes into the tram cars. Enough ore for the miners to stand on and reach the back is held in the stopes, so that when a stope is beaten out to the level above it is practically full of broken ore, which amounts to about one-half of the ore originally in place in the solid.

The ore is hoisted in self dumping skips and the underground stations are equipped with ore pockets and gates for loading the skips.

These pockets are so arranged that the ore cars can pass over them and dump their loads through grizzlies of steel bars or rails which hold back large boulders (that make trouble in passing through the bin gates or the feeders in the mill) where they are broken up with sledge hammers until small enough to pass between the bars into the bin below.

Mine Equipment

As none of the fluorspar mines are over 650 feet deep the hoisting equipment required is not large.

Sinking is done with the jackhammer type of drill, drifting and crosscutting is generally done with a mounted type machine, sometimes with a jackhammer where the ground is not too hard and a Waugh turbo type where more power is needed. Stoping is all done with air feed hand rotated stoping machines.

Pumping equipment is of great importance as the mines are wet. Under normal conditions the Fairview Company pumps about 1,500 gallons per minute and the Rosiclare Company about 700 gallons per minute, but in

times of high water in the Ohio River the flow of water increases to double these figures.

Both of these mines are deeper than the Hillside mine which is mining in drained territory and has no water to speak of.

Fig. 3—Showing two of the four five-compartment jigs used in separating the fluorspar from the impurities at Hillside Mine, Rosiclare, Ill. Each jig works a feed of different size, graded from large to small.

Milling

To produce the commercial grades of spar demanded by the market it is necessary to mill the run of mine ore. The typical flow sheet of a modern spar mill would be substantially as shown in Fig. 4.

The flow sheet, it will be noted, starts at the storage bin. The reciprocating feeder pushes the mine run ore into the revolving washing screen where the under-size goes to the dewatering cone which eliminates the slime and waste and carries the untreated spar to crushing

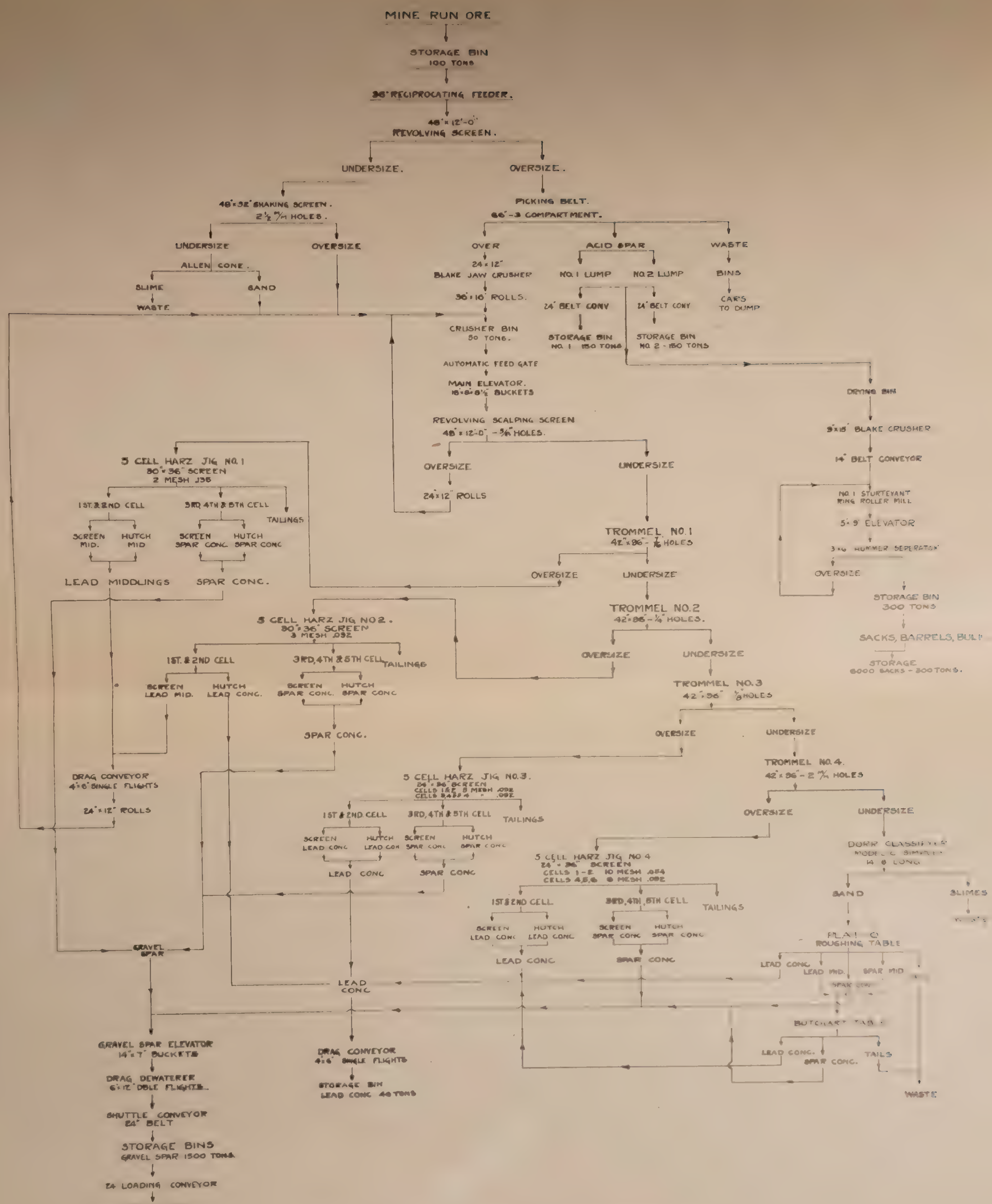

Fig. 4—Typical flow-sheet of a modern fluorspar mill.

rolls. The over-size goes to the picking belt where waste is thrown into bins, and what is left of the mill run ore is separated into acid spar and that going to the crushing rolls, sizing revolving trommels, jigs and concentrating tables as is shown in the diagram, and various conveyors and elevators. What galena concentrate is present is eliminated on the jigs and tables and carried by a conveyor to a storage bin.

The gravel spar is carried from the various operations to a large elevator which lifts it to a dewatering conveyor, carrying spar to the storage bins, where it is distributed to the various bins by means of a shuttle conveyor. The loading of the spar is from hoppers under the bins through an automatic distributor onto a belt loading conveyor which carries the washed spar to the car loading equipment at the railroad tracks.

Some of the elements of the cost of producing fluorspar are labor, fuel, dynamite, timbering, supplies and spares, pumping of water, depletion of ore bodies, depreciation of plant and equipment, the carrying of a supply of broken ore, dead work such as drifting, cutting of stations, and working through lean deposits. There is always present the uncertainty of the nature of the deposit as it is being worked, a large investment in a modern fluorspar mining operation, which is entitled to a fair return, and last but not least the fact that the investment is highly speculative.

The Bureau of Mines has completed its fluorspar investigation of this year and says: "The importance of fluorspar in the steel and ceramic industries is so great and accurate information on methods of mining, milling and utilization, and on costs of production of fluorspar is so lacking that it has been considered advisable by the Bureau of Mines to investigate all phases of the fluorspar industry in the United States. At the request of and in company with several Eastern fluorspar producers, examination has been made of the principal fluorspar deposits of the Western States.

This examination was followed by an intensive study of the producing mines in Illinois and Kentucky. It was found that most of the deposits of the far Western States were small and could not be relied on to produce such surplus over the needs of the Western States. Costs of production in the Illinois-Kentucky field have increased greatly owing to the increasing depth of the principal mines, the large amount of water that must be pumped and the increased cost of labor and supplies. A report of all phases of the fluorspar industry is in preparation."

Notwithstanding the large existing demand for fluorspar under normal conditions, which is constantly increasing, owing to the general increase in business and from new uses found for it, I feel it is not necessary that a substitute should be found, as with an increase in price, old mines and prospects in the Illinois-Kentucky field would be worked again as soon as a market price justified.

The same condition would again bring spar to the Eastern users from Colorado and New Mexico and importations from England and Germany would make up the deficiency, if any.

At succeeding levels of higher prices more and more production would come in until the demand was satisfied. An advance of a few or several dollars per ton would not be burdensome. Five dollars per ton would mean only 2½ cents per ton additional cost for steel ingots.

I think I am justified in saying that if necessary to insure an adequate supply the leading miners of fluorspar, if approached in the right spirit, with their knowledge of mining, with ample capital and expert engineering departments, would undertake necessary development work in the outlying districts provided the owners of prospects or local capital could not do so.

VICE-PRESIDENT TOPPING: Gentlemen, the Institute again thanks the various authors for the several papers

presented, and I would also say that in my opinion the papers I have heard today rank equally high with the preceding high mark that you have established heretofore. This I believe concludes the proceedings of this session and the meeting is therefore adjourned until this evening.

EVENING SESSION

The evening session of the Institute was held in the Grand Ballroom of the Commodore. After dinner, President Gary called the meeting to order. At the drop of the gavel there was applause which subsided at the second drop of the gavel.

JUDGE GARY: Thank you. No man if he willed it could say more than that. Please remember we are in the presence of discipline. We can teach a disciplinarian something. Please live up to the reputation I give you. (Laughter.) You have done it before many times.

Gentlemen, at the beginning I wish again to remind you that our old and much-beloved friend, Uncle Joe Butler, is still ill; but I am glad to say he is in good spirits, is able to be about, and has promise of life for a good many years to come.

Also our greatly admired and esteemed friend, Mr. Willis King, has been in rather poor health for the last three months, and although not able to be here this evening, is improving rapidly, and will soon be in good health, I trust.

From an affectionate regard for these old friends and associates I ask you to pay your respects, and with the hope in your hearts that these men will soon be restored fully to health and that they have before them a good many years of life and happiness, I ask you to rise and stand for just a moment.

(The assembly did this.)

Admiral Vogelgesang, Mr. Morrow, ladies and gentlemen: We are proud of the American Iron and Steel Institute. Comparisons are odious and we make none except to say that I think no better banquets or better

DINNER OF THE AMERICAN IRON AND STEEL INSTITUTE IN THE GRAND BALLROOM OF THE COMMODORE, NEW YORK, OCTOBER 27, 1922

audiences are seen in this great and perhaps greatest banquet hall of New York City than the ones which are carried on by the American Iron and Steel Institute. On this occasion, as on all others, it is well represented.

This Institute is what you have made it. You are the soldiers in this great industrial organization. You are respected and you are acknowledged to be a great, influential and responsible organization by the people of this country and all others, for you are widely known and recognized as leaders and successful marchers in the campaign for industrial stabilization which, in economic lines, is more needed throughout the world today than anything else. And this Institute will continue to be what you make it. As your president, whom you have honored with the position of the presidency from the beginning, I am very proud of the membership of the American Iron and Steel Institute.

I talked to you this forenoon and expressed some opinions in regard to the present situation. It would not be becoming for me to occupy any time in trying to make a speech on this occasion. You are anxious to hear the speakers, and I promise that you will not be disappointed.

This is the birthday of Theodore Roosevelt. (Applause.) For that reason this is Navy Day in the United States. In times of war the Navy is depended upon for the protection of the people and the property of our country. The Navy is always ready, notwithstanding everything that Congress has *not* done to make it so. (Laughter.) We do not always have the largest Navy nor the best equipped, but we always have a Navy, the members of which, individually and collectively, are able to cope with twice their number. (Applause.) I am not bragging nor doing anything more than stating what I think has been demonstrated. The Navy is not only ready to immediately start on their voyage wherever sent for protective purposes, but when they strike the shores of a foreign country, the Navy is first on the land

marching toward the enemy, as they did during the last great war when they were sent abroad, ready to fight.

And, gentlemen, if we ever have another war in which this country is engaged, which God forbid, you will see our Navy, small or big, very big in success at the front; and keep your eye, if you live to see that, upon Admiral Vogelgesang. (Applause.)

For a young man Admiral Vogelgesang has had a great experience and a long experience. As instructor, as officer in the Orient at the beginning, here again in the meantime occupying various positions of trust and duty as Chief of Staff, as commissioner or representative in South America, now in charge of the Navy Yard at Brooklyn, now drafted by our Government at the request of Brazilians to go again to South America and assist the Brazilian Navy to reorganize and complete a naval institution that will be worthy, creditable, and competent. I have great pleasure in introducing Admiral Vogelgesang. (Applause.)

Admiral Vogelgesang: Mr. President, and gentlemen: I feel as though I were in a very familiar atmosphere; not in the atmosphere that Judge Gary just put me in, but in the atmosphere of one surrounded by steel. I note that you have discipline too, which makes the atmosphere a little more perfect than it otherwise might be. But here I have a turret on my left hand, a turret on my right hand, and big steel guns all around me; and of course it is just as if I were on board ship. (Laughter.)

I am not going to endeavor to make a forensic effort tonight because I am incapable of doing that sort of thing in the first place, and in the second place if I get too much heated up I might run off into Portuguese on account of my recent South American visit and you might not understand all that I have to say. Moreover I think that this audience is one that rather deals more with facts than with fancies, and when you deal with facts you had better have your statement written out so that you can follow it and not go off into flights of fancy

that might lead you astray. We might say things which we would regret afterwards, especially when they appear in the press the next morning and are read in Washington. (Laughter.) So while this is an unaccustomed practice on my part, I am going to inflict it upon you for about ten or fifteen minutes; and I hope you will bear with me, because these are some facts I would like to have you take home with you.

It is exceedingly interesting and pleasing to meet you gentlemen who represent that great industry which is the backbone of our country's economic life—interesting and pleasing to me because I have the honor to represent that service, the Navy, which is at the same time the foster parent of the steel industry in this country and the backbone of our country's international political life.

You will recall that some months ago a group of the world's greatest diplomatic doctors met to study the effect of extracting some of the substance of that backbone and preparing a culture to inject as a serum into a sick world in the hope of restoring it to renewed life and vigor.

One result thus far apparent from this experiment is that it has acted as a stimulus to certain fanatical pacifists to proclaim with loud and far-reaching voice that the panacea for all wars has been found and that consequently there will be no more wars. These fanatics have gained a multitude of followers and have become a distinct national danger. They are producing a species of disease in our national life that demands the instant attention of all men whose intellects are normal and who read the world's history intelligently.

There is, of course, no such thing in the international pharmacopoeia as a panacea for war. War is a condition growing out of a perfectly natural desire of different peoples to progress and develop along the lines of their culture and ambitions. So long as the desire for progress and development exists in the human heart, so long will there be competition and strife between peoples for

the goal of their ambitions and national aspirations. This competition and strife may be begun with the greatest of good-will and resolutions of sincere amity, but in the end there must be yielding on one side or the other, which may entail a national sacrifice, or if there be resistance to yielding, friction develops which is likely to generate the heat of war. War is the ultimate expression of economic strife.

The average man is a productive and progressive creature. A nation is an aggregation of average people bound by racial ties or by community of interest, energized by a common purpose and inspired by the same spiritual ideals and motives. Like an average man, a nation must, if it wishes to survive, be productive and progressive. In the course of time these attributes of productivity and progressiveness will develop resources in a country that exceed its own capacity for absorption and its prosperity will depend upon its ability to find markets for its unabsorbed products.

We have now reached that stage in our development where we are producing beyond our power of absorption by about 20 per cent and our prosperity as a nation depends from now on upon developing foreign markets for our products. We are upon the threshold of that economic strife where we come into competition with other nations equally dependent upon foreign markets for their continued prosperity.

The question of power now begins to loom large as a factor in the successful solution of the problem. Other nations have sensed the importance of this factor long before, and having for centuries been forced into the foreign field for markets, have become thoroughly intrenched therein and have buttressed their positions by diplomatic or other more material power and will not tamely submit to any encroachment upon what they, from their own point of view, are justly entitled to consider their vested rights.

A navy is a bulwark of defense for the maintenance of those economic standards upon which the life and prosperity of a nation depend. Our history teaches us, gentlemen, how essential to our existence as a nation, in the past, your Navy has been; can you not see plainly how infinitely more necessary is your Navy to you in the future if we, as a nation, are to continue in our prosperity and not fall into decadence?

Will you accept the pacifists' logic and stand aghast that the maintenance of your Navy absorbs in times of peace eight per cent of the Federal budget? Is one-twelfth of our Federal budget too much to pay for the security of your prosperity?

Remember that a cheap Navy is an unjustifiable waste—for it cannot be effective. If you are to have any, it must be the best, and that is what we are proud to think you still have.

But let us assume that some of you still think that this insurance is too high. Let us see what premiums, if any, in peace-time are returned to you as dividends by your Navy for the investment in it of eight per cent of your yearly Federal budget.

What part has the Navy played in our national life in the past beyond its function as a bulwark of our national defense? Let us see if it can qualify as an industrial asset as well as a military asset.

It is a demonstrable fact, though to some of you it may seem an exaggeration, that the Navy has done more for science, commerce and labor than has any other department of our Government. It can be easily shown how much it has done for the building up of our national wealth through the stimulation of industry.

The great impulse to our industrial development was coincident with the conception of the so-called New Navy in the early 80's. In 1882, Congress passed an Act that provided for the construction of two cruising steam vessels, which were to be constructed of steel of domestic manufacture. How much steel was manufactured in the

United States in 1882? The shipbuilders of that period protested violently against this provision of the Act, because the steel industry of the United States could not furnish enough mild steel for the construction of two vessels, even though they were designed for less than five thousand tons displacement each.

Industry in the United States was content in that day to use wrought iron, and such steel as was used was imported mainly from England.

The steel, as then made, was of an inferior grade and did not come up to the Navy specifications. The American iron companies refused to erect the costly plants necessary to handle the new material required, unless they were guaranteed a volume of business that would justify the original investments in the plants.

These mills were built and the steel workers were forced to experiment until their products matched up to the Navy specifications. This was the beginning of our modern steel industry. The processes of manufacture were developed until the product was satisfactory and the steel men learned how to make good steel and learned further that so far as the success of their industry was concerned, it was cheaper in the long run to make good steel than it was to make poor steel.

Steel suitable for ship plates soon dropped from 8½ to 4½ cents a pound and brought this product, superior and cheaper in cost than the manufacture of wrought iron, within the reach of every industry. From this time on, steel began to supplant all other materials hitherto used in many trades and the great steel industry of the United States was fairly launched into its career of the greatest business of the world. The facts fully justified the statement made by Mr. Andrew Carnegie that the steel industry was built up on the United States Navy, whose contracts, specifications and inspections made steel what it is today.

The growing Navy demanded in addition all manner of cast, forged and machine steel. This called for better

and larger machine tools and this industry began to grow. America very soon became independent of Europe for machinery, and new items were added to our export trade.

The Navy, starting as the parent of industry, became its pacemaker. Each new set of specifications set the requirements a peg higher. The manufacturers never failed in the end to meet the specifications and, in the process of meeting it, there was a constant advance made in research and in the finished product.

Private industry is necessarily concerned with profit and must count the cost of material. The Navy is concerned primarily with the quality and not the cost of material; so that the Navy gives greater stimulus to industry than does private business.

The need for non-corrosive metals, special bronzes and alloys on board ship went a long way toward developing this industry.

The Navy Department organized and paid for the research that demonstrated the harmful effect of sulphur on steel and improved the manner of making it to give it its maximum strength.

These discoveries were turned over to industry with the result that the whole nation profited by a resultant increased safety and reliability of material that went into automobile, street car, elevator and like construction.

The armor plate industry has carried on more research into methods of treating and alloying steel than any other industry.

In the electrical field, the Navy was also the pioneer. Starting with the incandescent lamp, every new electrical discovery has been fathered and adopted by the Navy before its commercial use has been found practicable or profitable.

The Navy Department enabled the General Electric Company to produce the first electrically propelled ship. This development is one of the greatest in the art of ship

propulsion and has been adopted by us for all future battleships.

The great radio telegraph plants that now encircle the globe are owned and operated by the Navy. Without the Navy's interest, experiments and research, and substantial contracts to manufacturers, the radio industry in this country would be wholly in foreign hands.

The radio compasses that flank all our great ports are owned and operated by the Navy. By their use, any vessel can fix her position on approaching port in fog or storm as frequently as she desires it, and thus avoid delay and danger in making port.

The money spent for aviation is devoted to study, experiment and research, which in the end will go far towards bringing aviation into profitable commercial use.

So much for the Navy as an industrial asset in a material sense. There is more to be said for it as an industrial asset in a personnel sense.

The Navy has become one of the greatest trade schools in the world. There is scarcely a trade of major importance that is not represented on board ship. A battleship is a miniature industrial city, and every activity common to an industrial city is encountered there. A ship must be self-sustaining and everything that goes into its manufacture must be capable of restoration and repair.

The Navy mechanic, being chiefly engaged on repair work, gets a very much wider range of experience than those products of our civilian industrial system, confined to operating a single machine, and he becomes that very useful member of society known as a good all-round mechanic. There is a constant and steady flow of this character of personnel from the Navy into civil life and there can be no question but that industrial life is enriched thereby.

Every man that leaves the Navy is not by any means a mechanic, but they have qualified for the industrial life in a large measure notwithstanding, for if they have

learned no trade, they have developed in physical strength, they have improved in knowledge, they have an education in cleanliness, in self-restraint, in self-reliance and in discipline that is a tremendous asset to society.

Another peace-time activity of the Navy is that of protection to our trade and to our citizens abroad. There is no place so remote that is accessible by water, where we may have interests, that the Navy is not prepared to go to on call, if not already actually on the spot.

You will find our little river gunboats 1,700 miles up the Yangtse River in the heart of China, guarding our interests there, settling troubles and protecting our nationals. Our trade with China is about $145,000,000 a year. The cost of the Navy out there is $3,000,000.

Our Naval forces in the Caribbean protect our nationals and our trade throughout that area. The fruit trade alone of this area is worth $50,000,000 annually.

In closing, I cannot better express my sentiments than by quoting the words of a strong man, who said: "The naval officer is not interested in any one section of the country or in any one industry, but he is interested in the development of our country as a whole, in protecting our citizens, in fostering industry and commerce and especially our commercial interests abroad. He does not want war, but he does ask for a Navy as big as that of any other country and 100 per cent. efficient. He desires that his country's voice should be heard with equal attention to that of any other when the nations assemble around the council board. He knows that without a background of visible power we can neither preserve our prestige nor our national dignity, that we cannot protect our commerce or our citizens abroad, or be ready for battle when the crisis comes. Gentlemen, you need the Navy and the Navy needs your support. Our country and the world needs the American Navy. Let us make and keep it a good Navy."

I can only add to this plea, so well expressed by this gentleman, an injunction against a cheaper Navy. Make

effective your protest against a budget for the Navy that will, by its insufficiency prevent as it has during the past year our fleet training exercises so indispensable to fleet efficiency, that denies us the men that we know we need, and that stultifies efficient operations. Whose judgment are you, as big business men, as good hard-headed and sound Americans, going to support—the judgment of men whom you have been paying for for forty years to become expert in the science of our profession, or the judgment of political opportunists or misguided pacifists? (Applause.)

JUDGE GARY: We are very much indebted to the Admiral for his scholarly, instructive and very interesting address.

I am going to introduce now a lawyer, a banker, and, much better, a business man. I have drafted Mr. Morrow from the firm of J. P. Morgan & Company because he is one of our kind, because he is another man who will bear watching. (Laughter.) I use that term in the sense of saying he is one of the most active, the most important, and the most all around representatives of the highest class of business which is conducted by the firm of J. P. Morgan & Company, and which reaches today to the ends of the earth.

Many of you, perhaps most of you, are acquainted with Mr. Morrow. But none of you, perhaps, knows all that he is entitled to be credited with. He left a very active life of work and, what is more important, of thought, of mental activity, to come here this evening, because he knows something of you and wanted to know more of you; because he is interested in what you are doing, because he would always be glad to meet you, and always pleased to be helpful.

I take great pride and pleasure in presenting to you Mr. Dwight Morrow. (Applause.)

MR. MORROW: Mr. President, Admiral Vogelgesang, Mr. Schwab, ladies and gentlemen: It is a pleasure, a privilege and an honor to be permitted to be here this

evening as your guest. Judge Gary said that I would bear watching. I suppose he feels that way about us all, and that that is the reason why the photographer has just taken a double photograph of us, one from one end of the room and one from the other. It makes me think of a story told by General Bingham, once Police Commissioner of the City of New York. It was at a time when the new method of identifying malefactors was being put into practice. They took not only the fingerprints of a man, but also three photographs—a view from the front, a view from the right and a view from the left; and if he had a mustache they took three with the mustache and three without. A malefactor escaped from General Bingham's custody. They sent six pictures of this man out from headquarters over the city with instructions to apprehend him. One diligent officer somewhere in Flatbush telephoned, at the end of three or four hours: "I have caught five of them and I expect to catch the sixth before night."

I had the pleasure once before of being at one of your dinners. It was the dinner you gave to Marshal Foch, and I remember what he said about the Iron and Steel Institute—how earnestly he expressed the great debt that the allied nations owed to what you had done during the war. I thought tonight as I looked at this great group of men who have been banded together for more than twenty years, almost a generation, what a great factor you had been and what a great factor you are in the industrial and economic life of the world.

We are now so close to the shadow of the Great War that we cannot help but think in terms of its terrible toll of life, of the great destruction that it wrought. But I sometimes think that when we get far enough away, when those who come after us study the century that we are passing through, perhaps the war, big as it will loom, will not be the biggest thing in the century.

It seems to me that the most arresting fact of the century has been large scale production. The thing that has

affected it most, and will most affect the centuries that are to come, has been the thing in which you are engaged, large scale production, the doing of great things for countless people that you never see, that are very far distant from you.

One hundred or one hundred and fifty years ago most of the economic life of people was bounded by a circle that might have a radius of twenty or twenty-five miles. Except for a few favorably situated cities on seaboards there were very few communications. People lived in small communities and got things done for them by their neighbors. They in turn did things for their neighbors. Roads were bad and goods were hauled on the backs of horses or in primitive coaches except where the natural highway of the river or the ocean existed.

Within one hundred and fifty years there has come about this tremendous transformation of the life of the world. The coming of communications, the doing of things with machinery, have made it possible for men like yourselves and your associates, and when I say your associates I mean those who hold the highest positions as well as those who hold the humblest positions in your great industry, to engage in working for people that you never see, for people you hardly know about; and those people are engaged in working for you. Now that is a tremendous thing that has happened. It has brought a great responsibility upon men, it has greatly increased the standard of living of all men.

Take a dinner of this kind. Where did the sugar come from? Where did the coffee come from? People have worked all over the earth to provide a little of what we have had here this evening, just as we are working in our daily life for people all over the earth.

I think one thing is perfectly clear: that nothing has contributed more to large scale production than steel. Whether we think in terms of steel rails or in terms of steel ships, the whole problem of communications would be a far different thing than it is today if it were not for

what you men are doing in the steel business. It is not only your own large undertakings that depend upon you, but all of modern life depends upon the contribution you are making to the lines of communications which exist between the peoples in the various parts of the earth. It is steel that furnishes the new pathways of communication. It is steel that distributes the products of the men of one continent to the men of another continent. It is steel that enables the people of the various parts of this earth to serve each other as they were unable to serve each other a century ago.

Six centuries ago half the population of Europe was wiped out by a plague, because, when the local crops failed, the people died of malnutrition. They died because the world was not yoked together so that the food could be brought to them from those portions of the earth that had plenty. Large scale production with all of the world-wide variations in business that it has brought has tempered those great calamities that formerly fell upon individual communities. It has raised the standard of living all over the world, as evidenced by any one of the articles that we have in daily use today, that were not available, except to the few, two centuries ago.

Take a simple thing like sugar that I spoke of: two hundred years ago 1,500 tons of sugar were carried into England. It was classed among the spices, one of the rare things, that only the very well-to-do had. A century later 150,000 tons of sugar went into England. In the year 1900 1,500,000 tons of sugar went into England. Last year there were 4,500,000 tons of sugar consumed in the United States. That is the kind of thing that spreads itself out in the whole world. The standard of living has been raised, and is being raised, by the ability and energy and work of you and your associates, by the lines of communication that you have created, by the consequent economies of large scale production. And again, when I speak of your associates, I mean all the men joined with you in your work, from the humblest worker that comes

in as a casual laborer, to those who are directing your vast enterprises.

When one speaks of how much large scale production has accomplished in the comfort of the lives of the people of this earth, it is very easy to be misunderstood. One who recounts the superiority of the present over the past may easily be accused of ignoring the evils of the present. And the goal of all right-minded men should be to make the future as much better than the present as the present is better than the past. Now, I believe that the benefits of modern civilization are only beginning to be realized by the people participating in the work of modern civilization. You only have to examine the work of this organization to appreciate that fact. It is a credit to the man who has been your president for so many years that he is not satisfied with the existing system, that he is tireless in finding practical ways in which it can be improved. Go through the records of what you have done in your welfare work, the studied effort to get rid of the evils that come with large scale production, the quest for safety devices, the enlistment of more and more men in the ownership of your business, so that capitalists and laborers shall not be in two classes, but that little by little it shall be brought about that the capitalist-laborer shall own these vast businesses. That is what these stock participation schemes mean. The humblest worker who has part of the savings of yesterday has capital to that extent, and if he has invested those savings in the company for which he is working, he is not only a capitalist generally but he is a capitalist in that particular company. On the other hand, no one of you who may own your own businesses has ceased to be a laborer so long as you are helping to direct those businesses.

One of the difficulties of this large scale business is that most persons are laborers as to one industry and capitalists as to others. The great work that Judge Gary has done in enlisting the cooperation of his men in the United States Steel Corporation has been to create a con-

stantly increasing group of men who are capitalists and laborers as to the same industry, the United States Steel Corporation. That same thing has been carried on by Mr. Schwab and doubtless by many others of the men who are here tonight. It is only the beginning, but it is a most important beginning. And its end we cannot see. It is a great thing to be doing. It is a great thing not only for your own business, but also as an example to the other industries of this country.

You are engaged in a great work, and you all ought to be proud of it. As Judge Gary said, you ought to be proud of the position that this organization has made for itself in the world. The work you are doing should be an inspiration to you all. It is certainly an inspiration to those of your friends who are permitted to come to your meeting.

JUDGE GARY: There is one more speaker on the program. You could call his name. (Cries of "Schwab, Schwab, Schwab!") What shall I say about him? (Laughter.)

A VOICE: Tell the truth. (Laughter.)

JUDGE GARY: Tell the truth, and shame all of you, (Laughter.)

Mr. Schwab is a standby. He is a faithful, progressive, friendly, successful competitor and associate. Not all of you occupy that position (laughter)—yet.

It is a great thing to have a man with great ability, courage and faithfulness, at once patient and helpful, stand with us and for us and fight against every opposition, but fight openly and fairly. Mr. Schwab has been faithful and persistently helpful from the time of our first meeting in 1907. He has reached the position now where he cannot be other nor less than that. The more a man succeeds, the higher the position he reaches, the more difficult is it for him to do anything that would be disloyal to the organization to which he is attached.

I am not trying to tell you about him nor to do more

than express a few words of personal appreciation of the man, every word of which you subscribe to.

I now present our greatly admired and our much beloved associate, Mr. Schwab. (Applause.)

Mr. Schwab: Mr. Chairman and fellow associates of the Iron and Steel Institute; our distinguished friend Admiral Vogelgesang, and most eminent financier, Mr. Morrow:

I find that the Judge hesitated a good deal in finding something to say about me. (Laughter.) He started off with great fluency in introducing the other two gentlemen, and I have been wondering whether his difficulty in finding words to introduce me were that he knew me too well (laughter), and that somebody in the audience said, "Tell the truth."

I greatly regret that I was not able to attend your meeting and meet you all at the last banquet. There were good reasons for that. Topping, Dinkey, Grace, Block, and the rest of the fellows were having a pretty lively time down here at hearings. I thought the atmosphere of the Alleghany Mountains was a little more healthful, so that much as I desired to be here, the preponderance of evidence, if I may so put it, was in favor of my staying up there. (Laughter.)

Now I have always had a very great admiration for these men. Dinkey I brought out in the mills of Homestead and I knew that he knew all about the business as well as about the politics of the business. Topping, Block, Jim Campbell and all these fellows who testified at this hearing, showed such an utter lack of knowledge about the steel business (laughter) that I do not mind saying I was heartily ashamed of them as fellow associates. (Laughter.)

I always start my remarks at these meetings by saying something with reference to Judge Gary, in admiration of the work which he has done and his leadership of this our great industry.

Never have I known an organization to be built up

DINNER OF THE AMERICAN IRON AND STEEL INSTITUTE IN THE GRAND BALLROOM OF THE COMMODORE, NEW YORK, OCTOBER 27, 1922

so successfully, or with so much enthusiasm or good fellowship, as this association, the American Iron and Steel Institute; and to Judge Gary, above everybody else, belongs the credit for that loyalty and love of coöperation which he has so persistently instilled into the hearts of all of us. (Applause.) I have said this so often, but I demand it as my privilege in the name of the members of the Institute to say to the Judge thus publicly before you all, how much we are indebted to him for his work; how loyal we shall always be to him and his projects and endeavors; how we shall miss him if any of us live after he has ceased to preside over this Institute—which God save may be many years; how we will stand by him through anything that he proposes, because he will propose nothing that is not beneficial and honorable: long live the president of this Institute. (Rising applause.)

You know the Judge in his eminent position ought to be jealous of no one; the head of this greatest institution in the world, with a reputation throughout the universe for skill in administration of great affairs, successfully conducting his great corporation for so many years; and yet I have come to the conclusion that he is jealous, and I will tell you why (laughter). When I reached a place in the steel world that I felt entitled me to some relaxation and change of employment I decided to become a farmer; so I went up to Cambria County and started a farm. I began to raise cattle, sheep, pigs and all that sort of thing. Now the Judge ought not to be jealous of that, and yet I seldom pick up a paper that I do not see the Judge as a farmer. (Laughter.) I just saw one this afternoon, and it shows the Judge in profile standing by one of his favorite cows: all I need say to convince you that the Judge is no farmer is that he is standing on the side of the cow which, if she had been a self-respecting cow, would have kicked the stuffing out of him. (Laughter and applause.) I do not mind saying that if he does not stop this opposition in the farming

and cow-raising business I am going to buy his Steel Corporation. (Laughter and applause.)

I saw the record of a thoroughbred bull the other day, and sent the pedigreed animal complimentary to Judge Gary, thinking I would win his good will. The pedigree of this bull was "Sired by Florin, dammed by" so and so. Well, the Judge thanked me for the bull, but he said, "I wish you would send me one that is not damned by anybody." (Laughter.)

I said to the Judge tonight, "I do not know what I am going to talk about tonight." He replied, "Oh, tell them some of your old stories." That reminded me that one of Al Dinkey's nieces, a nice little girl, came up to my place at Loretto some time ago. My father and mother were present; I wandered into that religious atmosphere—in which I so well fit (laughter),—to convey the impression that I conducted my household as becomes that community; so I said grace; and this little girl listened and finally turned to her mother and said, "Mother, don't Uncle Charlie know any other stories?" (Laughter.)

When I do not know what else to talk about I talk about Loretto. Loretto is some place, you can believe me! A short time ago we had a visit from Garry Kerr and Homer Williams. I happened to be down at the lower part of town. I said, "Won't you walk up to the house and have a drink?" Homer said, "Walk! let's run." (Laughter.)

You know Grace and these boys associated with me at Bethlehem have been going around buying steel works, ship yards, and Lord knows what else—surreptitiously. (Laughter.) Up in Loretto everybody that has anything they do not want, tries to sell it to me. (Laughter.) One old fellow came along one day with an old white mule, just as I was walking into the garden. You know I told you about the cow a man wanted to sell me last year. Well, this fellow wanted to sell me the mule. "What do I want with that mule?" I asked. "He is blind and half

dead, at any rate.'' With that I gave him a punch in the side with my cane, when this old mule suddenly pricked up his ears and kicked out behind and hit the old fellow in the stomach; then he pranced around over the grape arbor, tore down the vines and jumped into the middle of my wife's favorite canna bed, and to wind up jumped into the hothouse and raised the very dickens. I remarked to the fellow, ''He is not blind, nor dead, is he?'' ''No,'' he said, ''he is just one of those onery, contrary cusses that does as he pleases, like you do in the steel business.'' There is the reputation that I have. I like that old mule. But there are other compensating circumstances. I decided in my opening remarks not to talk to you upon technical subjects. (Laughter.)

One thought which I might be able to give you is of a sentimental character. It has not been the dividends, it has not been the money that has been the chief return that I have had in my forty-three years in the steel industry. The greatest dividends I have ever received are the dividends that have come to me in the shape of good fellowship and friendship of the members of this Institute. (Applause.) Nor would I exchange all that I have for that pleasure which comes to me at this late date in life.

The Admiral has spoken of the difficulties of making boiler plate and ship plate in 1882. How well I remember that. Homer remembers it. Garry Kerr, Dr. Unger, Al Dinkey, all the rest of the fellows at the Homestead Works, that had to try to make Government boiler plate in 1882, remember it. He speaks of the high quality he got. I should say that he had better speak of the high quality that he thought he got. (Laughter.)

I will never forget when Corey was asked by a Government investigating committee why he had stretched the test pieces, he tried to say something about the moment of inertia, the radius of gyration, and that sort of thing. But one of the committee said, ''That is all right, Mr. Corey; but why did you stretch the test pieces?''

It was one of the things that our distinguished Admiral did not know.

At one of these investigations Klein, who did the armorplating—and tempered it a little different from your specifications, Admiral—was asked why he did so. I had Klein trained for three weeks as to the proper answer. I sat in the corner and shook my head when I saw he was going wrong, and one time when he was indeed going wrong I shook my head violently. He looked at me and said, "Hang it, Charlie, that is what you told me to say." (Laughter.)

But there is one true thing, the difficulties of making plates, structural, armor and other plates, to the Government specifications, were of such a character that we were compelled ultimately to make better steel, to meet these specifications; it reflected on the output of the entire steel products, whatever the line. Therefore I have no hesitancy in seconding everything that the distinguished Admiral has said, because it was based to the best of his knowledge on information received. (Laughter.) But the ultimate outcome of it was exactly as he said, that there was no element that contributed more to the upbuilding of the quality of steel than the United States Navy specifications for shipbuilding.

Gentlemen, I am not going to detain you long. We were late in coming in here. The Judge said he had a good dinner at home and he could not get through it in time to get here. (Laughter.)

The hour is growing late. I am getting old—you know, since I last saw you boys I have passed my sixtieth birthday; I am now the real old man of the American Iron and Steel Institute from point of service and I am sorry that the years are not many when I can come and join you all, and hear your plaudits, your words of friendship, than which no music is sweeter to my ears, words of approval and encouragement from this crowd. When I retired to Loretto this summer, I met a doctor friend up there. I said, "I have pretty well given up

business now. I am not doing much. Grace and the boys down at Bethlehem and other places are taking the responsibility and I am just touching the high spots and keeping out in the country." I said, "Doctor, I wish you could insure me twenty years more of life. I would go ahead in this industry." He said, "You are a pretty healthy looking specimen. Do you smoke?" I said, "No, I do not smoke." He said, "Do you drink?" I said, "No, I do not drink." He said, "Do you play good golf?" I said, "No, I do not play good golf." He said, "Do you have any vices?" I said, "No." Then he said, "What do you want to live twenty years longer for?" (Laughter.)

I will tell you why I want to live twenty years longer. I want to live twenty years to come down to this Iron and Steel Institute. I want to live twenty years to see all the members of this Institute happy, to meet here each year to renew old friendships and old acquaintances. I want to live twenty years to congratulate Judge Gary on his forty years presidency of the Iron and Steel Institute. I want to live twenty years to see all you boys play as good a game of golf as I do. I want to live twenty years to meet our distinguished guests from all over the country that come here to honor us with their presence upon this annual occasion.

We have two distinguished guests here tonight. I thought there was an ulterior motive in having them here too. Judge Gary planked on one side of him the representative of the greatest banking house in America, with all its gold and wealth—which he is going to need if he keeps on farming (laughter); and planked on the other side of him the distinguished Admiral of the American Navy, proverbially known as the best farmers in the world: you know you always hear about the naval officer riding a horse or doing something of that sort; you know we all wish to do that which we know least about. It is a curious thing, a curious trait; we want to do that for which we are least qualified. The Admiral

just confided to me that he would like to be a farmer. I suppose he confided in the Judge and that is the reason the Judge has him here tonight.

I want to live twenty years to see the Judge's farm a real producing farm. I read in the paper the other day that he raised 150 capons and someone stole them the next night; and that his pigs took the cholera and none of them were left. Well, I want to live twenty years to see the product of Judge Gary's farm, which product will be the real wonder of this age. I want to live twenty years to see the marvelous developments in the iron and steel industry.

Mr. Morrow spoke of the consumption of sugar. I can speak of the consumption of steel. Be optimistic. I have said to you before that I never builded a works that was sufficiently large to meet the requirements of the future. However old, I am just as optimistic as I have been all my life. Go forward with confidence. If you have no money to go forward with, borrow the money and have confidence that American industry is going to be able to pay it back. We have here the resources that will make American industries great. It needs only the touch and skill of the gentlemen in this room in the iron and steel industry to bring them to life, wealth, fortune and prosperity in the years to come.

Happiness—prosperity which we are now in or at least upon the eve of, is going to be the part of the iron and steel manufacturers. Be happy and above all have sentiment in business. Remember your friends. Act with confidence, friendliness, cooperation and all the principles that Judge Gary has instilled into us in the promotion of this great Iron and Steel Institute.

May your life in the business be as happy as mine has been. May your associates and friends be as dear to you as you are dear to me; and I can wish no man a greater return for his labor in the development of the great iron and steel industry in the United States. (Applause.)

JUDGE GARY: On behalf of the Institute I thank you for being here. I thank those who produced the splendid papers for today. I thank the distinguished guests who have favored us by their presence and their beautiful, magnificent addresses, and I thank Mr. Schwab for his entertainment (laughter), a part of which is absolutely true (laughter); and I bid you good-night.

PARTICIPANTS—MAY MEETING

(*Guests)

Abbott, Franklin E.
Abbott, William H.
*Adams, Robert J.
Affleck, Benjamin F.
*Agler, Ben A.
Agnew, James C.
Agnew, John D.
Ahlbrandt, George F.
Akin, Thomas R.
Alderdice, George F.
*Allan, George
Allderdice, Taylor
Allen, John N.
Alley, James C.
Amaden, Edwin A.
*Amis, F. W. T.
Anderson, Brooke
*Anderson, George L.
Anderson, N.
Anderson, William A.
*Andrews, F. D.
Andrews, Joseph B.
*Applegate, P. R.
*Armstrong, L. B.
Armstrong, Victor C.
Arnold, L. L.
*Arthur, H. A.
Arthur, Thomas A.
Assmann, F. A.
Atcherson, R. W. H.
*Atkinson, L. H.
*Austin, F. G.
Austin, Harry L.
*Ayres, C. T.

Baackes, Frank
Baily, T. F.
Baker, Edgar D.
*Baker, Frederick H.
*Baker, P. R.
*Baker, T. M.
Baldwin, R. L.
Balkwill, George W.
*Balliett, B. J.
*Bancker, W. F.
Banks, R. M.
*Barbour, James W.
Barnes, E. Austin
Barnes, Fuller F.
*Barnum, J. P.
Barren, Henry A.
Barrett, J. C.
Barrows, W. A., Jr.
Barrows, W. A., 3rd
*Bart, B. F.
*Bartlett, Lyman
*Bates, C. R.
*Bates, H. W.
*Batteiger, R. L.
*Baur, Charles S.
*Baylies, F. N.
Beale, A. H.
Beale, H. A., Jr.
*Bean, Henry Willard
Beaver, Harry C.
*Becher, Eugen
*Beck, E. A.
Becker, Jos.
*Becket, F. M.
Beegle, F. N.
Bell, C. H.
Bell, G. Graham
*Bellamore, David
*Bendixen, C. H.
Bergquist, J. G.
*Berton, E. D.
*Bertsch, George F.
Best, Leigh
*Biddison, N. D.
Billard, J. D.
*Bingaman, Ralph W.
Birney, E. H.
*Black, J. B.
Blackwell, Harry E.
Block, Leopold E.
Block, P. D.
*Blodgett, John H.
Blowers, William B.
Blum, Julius
*Bolton, Julian C.
Bonner, James B.
*Bonner, Leonard A.
*Bonney, Carl
*Booth, H. C.
Booth, Lloyd
Bothwell, W. J.
*Boulware, A. L.
Bourne, Henry K.
Boutwell, Roland H.
Boutwell, Roswell M.
*Bowman, J. R.
*Boyd, James
Boyd, P. M.
Boyer, Pearce F.
Bradley, Carl D.
Bradley, Harry S.
*Bragg, A. J.
Braid, Arthur F.
*Brandeis, Eugene
*Brangham, W. T.
Brassert, H. A.
Breeden, William
*Bridgman, George M.
Brion, A. E.
*Brion, Lester E.
*Brittan, B.
Brokenshire, E. L.
Brooke, George, 3rd
Brotherton, Fred C.
*Brown, C. H.
Brown, Fayette
Brown, Frank L.
*Brown, Harold B.
*Brown, W. A.
Brown, Walter T.
Browne, deCourcy
Bruce, Robert A.
Brunke, Frederick C.
Brunner, John
Buck, C. A.
Buck, Leonard
Budd, Russell B.
Buffington, E. J.
*Bullen, J. H.
*Bulmer, W. C.
*Bunn, F. W.
Burden, I. Townsend
Burden, James A.
Burton, Carroll
Bush, D. Fairfax
Butler, Gilbert
*Byers, Maxwell C.

*Callow, W. K.
*Calloway, B. G.
Campbell, James A.
*Campbell, John McK.
Campbell, Louis J.
*Campbell, Wilson A.
*Cannon, Russell A.
Carhart, Perry E.
*Carley, Leonard R.
Carney, Frank D.
*Carr, Francis
*Carroll, E. H.
*Carroll, L. S.

*Carroll, W. J.
Carruthers, John G.
Carse, David B.
*Carse, John B.
Carse, John Bradley
Carson, George C., Jr.
Carson, Harry D.
*Carswell, J. B.
*Carter, G. O.
*Casey, F. Y.
Casey, John S.
*Casterton, J. W.
Cebrat, Paul
Chapman, William B.
Charls, George H.
Cheney, R. K.
Cherry, Cecil A.
*Chisholm, C. G.
Christ, Ernest W.
*Church, Warren D.
Clack, C. T.
*Claney, C. D.
Clarage, Arthur T.
Clark, Edward F.
Clark, Eugene B.
Clark, Frank E.
*Clark, K. L.
*Clarke, Harold B.
Claypool, George L.
*Cleese, Charles, Jr.
*Clements, B. A.
Close, Charles L.
Cluff, Charles C.
Clyde, W. G.
Coffin, William C.
Cohen, Frederick W.
*Colesworthy, Frank E.
Colladay, Frank H.
*Colling, A. F.
Collins, Edward C.
Collord, George L.
*Condit, Edward A., Jr.
*Cone, Edwin F.
Connell, Frederick
Cook, Howard H.
*Cook, O. W.
*Cook, Sam
Coons, Perry T.
Corey, Alfred A.
Cornelius, Henry R.
*Cotter, Arundel
*Cousins, Col. Arthur S.
*Cousins, R. W.
Cox, Walter S.
Craig, Sam N.
*Craig, William W.
Crawford, George G.
*Crawford, H. C.
*Creem, Daniel J.
*Critchett, J. H.
Crocker, George A., Jr.
Crosby, George H.
*Crosby, George H., Jr.
Crotsly, A. W.
*Cueman, J. Bentley
Cummings, Silas H.
*Cunningham, George
*Cunningham, W. H.
*Curley, J. F.
Custer, L. R.

*Dallas, C. D.
Dalton, Harry G.
Daly, J. P.
Damerel, George
*Dana, Richard H.
Danforth, A. E.
Davey, Albert I.
Davey, F. Austin
Davey, Harold
Davey, James G.
Davey, John
Davey, Samuel
Davey, W. H.
Davies, George C.
Davis, Stewart A.
*Deacon, H.
Deericks, Joseph G.
De Lano, Sterling P.
*de Munnick, O. M.
*Deneyven, G. W.
*Deppeler, J. H.
Desmond, John F.
*Detmers, A. C.
Deutsch, Lee
Deutsch, Samuel
*Deutschbein, H. J.
*Devaney, M. J.
*Dice, Agnew, T., Jr.
Dickey, William C.
*Dickson, Philip S.
Diehl, Ambrose N.
*Diehl, F. W.
Dilks, Lorenzo C.
Dillon, A. H.
Dinkey, Alva C.
*Dirkes, F. A.
Ditto, M. W.
Dodd, A. W.
*Donnelly, C. S.
Donner, Joseph W.
Donner, Robert
Donner, William H.
*Doolittle, H.
Dorman, A. D.
Dorman, Pliny O.
Dorsey, Richard M.
Dougherty, J. W.
Dowling, Eugene
*Downey, Col. L. E.
Downs, George F.
*Dressel, J. C.
Duane, James, Jr.
Du Bois, Henry C.
Duncan, John
*Duncan, J. W.
Duncan, W. M.
Dunsford, J. R.
Dwight, Arthur S.
Dyrssen, Waldemar

Easton, Harry M.
Eaton, Clark D.
Eaton, Wyman
*Edgerley, W. H.
Edwards, Edward T.
Edwards, G. L.
Edwards, James H.
Edwards, Victor E.
*Elkin, W. S.
Elliott, Charles H.
Ellis, Frank I.
Endicott, George
*Ennis, Joseph B.
*Entwisle, E. F.
Entwisle, E. B.
Eppelsheimer, Daniel
Estep, Frank L.
Evans, George D.
Everhart, W. H.
Eynon, David L.
Eynon, David L.

Farrell, James A.
Farrell, John J.
Farrell, Ralph G.
*Farrell, W. K.
*Faulkner, George
Fedder, Walter P.
*Feild, A. L.
*Fernald, Benjamin G.
Field, Herbert E.
Filbert, W. J.
*Fillius, George T.
*Finch, J. H.
Findley, Alvin I.
Fisher, Charles A.
Fisher, P. L.
*Fiske, W. H. L.
*Fleming, James
Fleming, W. J.
Fletcher, John F.
Floersheim, Berthold
Follansbee, William U.
Follet, Louis
*Fontaine, S. S.
*Foote, Charles M.
Foote, George C.
*Forbes, Alvin
*Forbes, B. C.
Forbes, William A.
*Ford, J. W.

*Forker, J. N.
Forster, Charles H.
*Forster, W. C.
Foster, Edwin C.
Foster, Frank B.
*Foster, R. L.
Foster, T. J.
Fowler, A. A.
Fownes, William C., Jr.
France, James H.
*France, William A.
Francis, Lewis W.
Frank, F. J.
Franz, W. C.
*Frederick, Leopold
Freeman, S. S.
*French, Field Marshal
French, S. S.
*Frew, Walter E.
Freyn, H. J.
*Froggett, J. F.
Froment, Eugene McK.
*Frost, F. R.
Fuller, Fred M.
*Fuller, Harry
Furst, J. K.

*Galbraith, A. T.
Gardner, K. C.
Gardner, William
Garritt, George
Garvey, Hugh J.
Gary, Elbert H.
Gaskill, Joseph W.
Gathmann, Emil
Geesman, W. H.
Gerry, Roland
Gessler, Theodore A.
Gewecke, J. H.
*Gibbs, E. A.
Gibbs, E. Everett
*Gibson, T.
*Gifford, Frederick C.
*Gifford, W. S.
*Gille, Harry S., Jr.
Gillespie, John M.
Gillispie, R. W.
*Gilmour, W. T.
Girdler, T. M.
Glass, Alexander
Glass, Andrew
Glenn, Thomas K.
Goddard, John N.
*Goldschmidt, Karl
*Goldschmidt, Theodore
*Gomber, William J.
Gordon, F. H.
Gordon, Peter J.
*Gove, W. G.
Grace, Eugene G.
Graff, Everett D.
Graham, Charles J.
*Graham, Harry E.
Graul, Carl L. O.
Gray, James H.
Green, William McK.
Greenawalt, John E.
*Greene, Edgar F.
Gregg, Robert
Gresham, William B.
Griffin, J. C.
*Griffiths, L. J.
Grose, James H.
Gross, John M.
*Grove, L. N.
Grugan, Justice F.
Gruss, William J.
Guba, Philip M.
Gummere, William
*Guttzeit, C. W.

*Hacke, A. K.
Hackett, S. E.
Hadley, C. O.
Haggerty, Frank L.
Haggerty, H. W.
Hall, Rollin S.
*Hall, W. S.
Hallman, Harry F.
Hamilton, Alexander K.
Hamilton, H. V.
Hammond, James H.
*Hammond, J. Sidney
Hancock, W. W.
*Hand, H. S., Jr.
Handy, James O.
Hansen, T.
*Harbaugh, Donald
Haring, Willard S.
Harper, Albert M.
*Harris, Charles
Harrison, E. W.
Hart, Charles
*Hart, Walter H.
*Haslam, E. H.
Hatfield, Joshua A.
Havemeyer, John F.
*Hawks, Albert W.
*Hay, Wren
*Hays, George O.
*Hays, William C.
*Hazelwood, Stuart
Hearne, W. W.
*Hedgcock, W. E.
*Heilman, G. H.
*Hein, Mr.
*Henderson, John
Hendricksen, J. J.
*Heneage, H. R.
Henshaw, John O.
*Herington, C. F.
*Herington, P. R.
Herman, Frank J.
*Herr, D. D.
Herrmann, Charles E.
Hettiger, Edward P.
Heyward, Thomas R., Jr.
Hickok, C. N.
Higgins, Dean
Higgins, W. B.
*Higinbotham, N. J.
Hildreth, Thomas F.
*Hill, R. E. Lee
Hilt, Samuel W.
Hird, R. G.
*Hirsch, Marx
Hirschland, Franz H.
*Hitner, W. Perry E.
Hobson, Robert
Hodge, Edwin, Jr.
*Hodges, C. W.
*Hoe, Arthur
Hoerle, Frank D.
Hoffer, Allen
Hoffman, William L.
Holding, James C. C.
Holliday, A. H.
Holloway, William W.
Holmes, Carroll O.
Holzworth, C. R.
*Hoot, J. C.
*Hopper, F. R.
*Horne, R. J.
Horner, William S.
*Howard, Abner U.
Howard, Clarence H.
Howard, John J.
Howell, Alfred C.
Howell, H. P.
Hoyt, Elton, 2nd
*Hoyt, F. H.
Hubbard, Paul H.
*Huber, Nelson
Hufnagel, F. B.
Hughes, Edward
Hughes, Harold L.
Hughes, I. Lamont
Hughes, John
*Hughes, W. H.
Hughes, William H.
Hulst, John
Humbert, Frank U.
Hume, J. E. N.
*Humphrey, G. M.
*Humphrey, Harry T.
*Humpton, C. F.
*Humpton, W. G.
Hunsiker, Harold W.
Hunter, Arthur H.
Hunter, John A.
Huston, A. F.
Huston, Frank R.

*Hutchinson, George
Hutchinson, O. N.

*Igoe, Peter
*Ireland, J. Morris
*Irons, Henry C.
Irons, Robert H.
Isham, Phillips
Ives, E. L.
Ives, Lee E.

*Jackson, J. A.
*Jackson, V. P.
James, Henry L.
James, Mark S.
Jameson, A. H.
*Jamieson, F. E.
*Jayne, J. T.
*Jennings, J. E.
Jennings, Robert E., 2nd
Jewell, Thomas M.
Johnson, Frank H.
Johnson, M. E.
Johnson, Percival
*Johnson, T. M.
Johnston, A.
Jones, B. F., 3rd
*Jones, Evan
*Jones, Frank W.
Jones, H. C.
Jones, Harry Ross
Jones, Henry L.
Jones, James C.
Jones, James D.
Jones, John E.
Jones, J. M.
Jones, Jonathan R.
*Jones, J. Raymond
*Jones, R. J.
Jones, Wm. Larimer, Jr.
Jones, William S.
Jowett, J. H.
*Joy, Maurice
*Joys, Carl C.
*Jump, A. P.

*Kandt, Fred J.
*Kauffman, E. J.
*Kelley, J. F.
Kellogg, Alfred O.
Kelly, M. B.
*Kelly, T. F.
*Kempe, A. F.
Kennedy, Hugh
Kennedy, James B.
Kenney, Edward F.
Kent, W. H.
Ker, Severn P.
Kernohan, Robert B.
Kilbourne, J. R.
Kilgore, Robert M.
*Kimball, William
King, Eugene W.
King, John M.
King, P. M.
*Kirkpatrick, H. B.
*Kister, Frank F.
*Klein, L. C.
Klingelhofer, George E.
Knapp, L. R.
Kneeland, Edward
Knisely, Edward S.
Konkle, C. M.
Korndorff, Lynn H.
*Kraeling, Harry A.
*Kreutzberg, E. C.
*Kreig, Charles
*Kruse, C. R.
*Kuegle, Paul C.
Kuker, S.

Lackner, R. A.
Lamont, Robert P.
Landon, Frank H.
*Landt, J. L.
*Langdon, Amon W.
*Langdon, P. D.
Langenbach, Edward A.
*Langenheim, Hay
Larkin, Joseph K.
Latta, William L.
*Laughlin, L. I.
Lawson, William B.
Lea, Robert C.
Leavitt, Avery T.
*Lee, H.
Leet, George K.
Lehman, Irvin F.
Le Van, Garrett B.
*Lewis, W. W.
*Light, N. D.
Linton, Robert
Lissberger, B.
*Lissberger, Max
*Littler, C. W.
Llewellyn, Paul
Locke, Wilbur Sargent
Logan, John W.
*Logan, John W., Jr.
*Long, Arthur M.
*Long, S. F.
*Loud, H. S.
Lovejoy, Frederick B.
*Lowe, L. J.
*Lowerre, T. P.
Lozier, Charles E.
Lucas, George C.
Lundie, John
*Lupton, Edward
Lustenberger, L. C.
*MacArthur, D.
*MacMillen, W. W.
MacMurray, James E.
MacQuigg, C. E.
McAlarney, John H.
*McArdle, J. J.
*McAuliffe, John
McBride, William
McCaffrey, Thomas
McCauley, John E.
*McClinton, Charles C.
*McCollough, C. A.
McConnell, John
McCook, Willis F.
*McCoy, E. J.
*McCracken, Fred. T.
*McDonald, A. E.
*McDonald, R. A.
McDonnell, E. J.
McElhany, Charles B.
McElwain, John
McFate, William M.
McGee, Harry L.
McGonagle, W. A.
McGraw, T. H., Jr.
McIlravy, W. N.
McIlvain, E. M.
McIntire, Charles V.
*McIntyre, W. W.
*McKean, Robert A.
McKee, Arthur G.
*McKee, Willis
McKenna, Roy C.
*McKillips, C. E., Jr.
*McKittrick, F. J. A.
*McNally, E.
*McNamara, J. F.
Mace, A. W.
Mackall, Paul
*Macon, William W.
Maguire, W. G.
Manchester, L. A.
Mann, Albert C.
Manning, W. E.
*Manson, F. M.
Manville, Tracy F.
Marble, A. B.
*Markey, John J.
*Markowitz, A. Lincoln
Marshall, C. D.
*Marshall, D. J.
Marshall, Edward E.
*Martens, Paul
Mason, Orland W.
*Mason, Ralph E.
Mather, S. Livingston
Mathesius, Walther
*Mathews, Albert
Mathews, John A.
Mathias, Thomas H.
*Matthews, C. H.

*Maxwell, Allison R.
*Maxwell, Joseph S.
*May, John
Meacham, Daniel B.
Meacham, Standish
*Merica, P. D.
*Merrill, C. A.
*Merritt, Louis
Mesta, George
Metcalf, Morris
Meyer, A. L.
Meyers, Frederick
*Miles, John
*Miles, T. V.
Miller, Charles L.
*Miller, F. C.
Miller, Harry J.
Miller, Herbert F., Jr.
Mills, Edwin S.
Mills, James R.
*Minuse, A.
*Modisette, R. B.
Moffett, Charles A.
*Mohr, G. K.
Mohr, J. A.
Moon, George C.
*Moore, M. M.
Moore, Philip W.
Moreland, W. C.
Morgan, W. H.
Morris, A. F.
Morris, Harry T.
Morris, Leigh B.
Morris, William J.
Morris, W. J.
*Morrow, Alan D.
*Mossman, Paul B.
*Moxham, A. J.
*Moyer, L. M.
Muchnic, Charles M.
Mueller, Otto
Mullally, R. J.
*Mullen, Edgar
*Mullin, W. J.
*Murphy, Deane J.
Murray, Joseph B.
*Murray, L. Weimer
*Murray, Thomas E.
*Murray, Thomas E., Jr.
*Myers, William J. Jr.

*Nason, Frank L.
*Nathan, Major W. S.
Naugle, H. M.
Neal, Albert D.
*Neave, A. A.
Neeland, M. A.
Nelson, T. H.
Newcomb, Charles H.
*Newman, R. K.
Newton, Peter A.
Nicholas, Richmond
Nichols, J. A.
Nicholson, J. H.
Nicholson, Samuel T.
*Nicoll, Courtlandt
Niedringhaus, Geo. W.
Nields, Benjamin, Jr.
Niemann, C. F.
*Nilsson, R.
*Niven, E. A.
*Nivison, R. E.
*Norris, Frank P.
*Norton, E. K.

O'Bleness, Henry M.
*O'Brian, Roland Lord
Ogden, F. A.
Olcott, W. J.
Oliver, W. H.
*O'Neil, Fred
*Orrok, H. D.
O'Shea, B.

*Palen, F. P.
Pardee, Homer A.
Pargny, E. W.
Parker, Edward L.
*Parrott, L. C.
Patterson, William J.
*Pauly, K. A.
*Peabody, F. E.
*Pease, M. H.
Peck, Claude J.
Peck, Hal H.
Peckitt, Leonard
Pendleton, John S.
Perin, Charles P.
Perry, John E.
Peters, E. V.
Peters, Richard, Jr.
*Petersen, Paul H.
Petinot, Napoleon G.
Pettis, Clifton D.
*Pettis, William M.
*Petty, D. M.
*Pew, J. G.
Pfeiff, Lewis
Pflager, Harry M.
*Phillips, F. Rees
Phillips, W. Vernon
Phillipson, Brainard F.
Pilling, George P.
Pilling, William S.
Piper, Arthur E.
*Pollak, Bernard E.
*Pollak, Julian A.
Pond, Clarke P.
*Porcher, Charles M.
*Porter, Rudolph
*Pouch, W. H.
*Poucher, R. I.
Pratt, R. H.
*Price, B. K.
Price, E. F.
Price, J. M.
*Pridham, Harold C.
*Prince, C. K.
*Pritchard, William H.

*Quilter, Frank
Quincy, Charles F.
Quinn, Clement K.

Ralph, J. E.
*Ramsay, A. J.
Ramsburg, C. J.
*Ramsey, George
*Ramsey, W. H.
Rand, Charles F.
*Rascovich, M. B.
Rawstorne, Charles D.
Raymond, Henry A.
*Readmon, H. P.
Ream, Louis M.
*Reason, E. L.
Reed, Walter S.
Reeves, Samuel J.
Reid, G. H.
Reilly, Edgar J.
*Remington, Franklin
Rentschler, Gordon S.
*Ribadeneyra, Antonio
*Richards, K. G.
Riddle, L. E.
*Riley, Walter C.
Robinson, C. Snelling
*Robinson, Dwight P.
Robinson, Theodore W.
*Rockwell, Fletcher
*Roemer, H. A.
Roesch, J. A., Jr.
*Rogers, H. E.
Rogers, William A.
Rogers, William S.
*Roland, C. F.
Romeyn, Radcliffe
Ross, L. P.
*Rotthaus, J. E.
Ruiloba, Jose A.
Rust, H. B.
*Rust, R. R.
Rust, W. F.
Ryerson, Joseph T.
Rys, C. F. W.

Sagendorph, G. A.
*Sanders, W. S.
*Sargent, Murray
Sattley, Elmer C.
Sauveur, Albert
*Savage, Edward
Savage, Joseph F.

*Savage, William D.
Sawhill, E. P.
Sawyer, Daniel E.
*Saxman, M. W.
Schaefer, Philip
*Schaumberg, Otto
Schleiter, Walter F.
*Schneider, A. E. R.
Schwarzenberg, E. A.
Scott, George C.
*Seaton, George W.
*Shannon, Randolph
Shants, G. Theodore
Sharkey, James L.
*Shaw, G. E.
Sheldon, Harry E.
Sheldon, S. B.
*Sheridan, R. J.
Shook, George L.
Short, G. W.
*Shoudy, Loyal A.
Sigafoos, Michael H.
*Simmons, Cary F.
*Simpson, K. M.
*Sinclair, Duncan G.
Sinn, F. P.
*Sinnott, W. C.
Skewis, Joseph R.
*Skinner, R. D.
Slater, J. A.
Sleicher, Charles A.
Slick, Edwin E.
*Sloane, Parker
*Sloane, W. D.
Slocum, Frank S.
Smart, George
*Smith, Acheson
Smith, Austin D.
*Smith, David H.
*Smith, Dudley J.
Smith, Floyd K.
Smith, Fred O.
Smith, James W.
Smith, Lewis R.
Smith, S. L.
Snyder, W. P., Jr.
*Solomon, H. Alfred
Solomon, Max
Souder, Harrison
*Southwell, Ray
Spackman, G. D.
Spackman, Horace B.
Sparhawk, Edward M.
Speller, F. N.
Spilsbury, H. G.
*Sproul, John R.
Sproull, E. Theodore
*Stacey, John A.
Stafford, Samuel G.
*Stahleker, Carl
*Stallforth, Fred

Starke, William H.
Stebbins, Howard S.
Steel, Charles C.
*Stevens, R. H.
Stewart, Hamilton
Stewart, Scott
Stillman, Charles A.
Stillman, J. S.
Stoddard, Harry G.
*Stoll, H. E.
Stoltz, Glenn E.
Strassburger, W. J.
Stratton, William H.
Striebing, George
*Studebaker, Clement S.
Sullivan, George M.
*Sullivan, Joe
Sullivan, William J.
Summers, Harry W.
*Summers, J. M.
Sussman, Julius L.
*Swank, Ralph
Swartz, Alfred H.
Sykes, Wilfred

*Taylor, Charles G.
Taylor, Clifton
*Taylor, F. H.
Taylor, Wade A.
*Taylor, W. H.
*Telles, Silva
*Thomas, C. G. M.
Thomas, Eugene P.
Thomas, George 3rd
Thompson, Edward D.
Thompson, George M.
*Thompson, J. I.
*Thomson, L. S.
*Thomson, W. Paton
Thorp, George G.
Thropp, J. E., Jr.
Tickner, Frank W.
*Tierney, J. T.
Tobias, William M.
Tod, Fred
Todd, William B.
Townsend, Herman E.
Toy, Francis L.
Tredennick, Harry L.
*Treharne, E. B.
*Tschirky, Leopold
Tutein, Dexter A.
Tutein, E. Arthur
*Tuthill, Stephen S.
Tweed, George P.

*Ulrich, Knox S.
Unger, John S.
Uphouse, Harry G.

Valentine, S. G.
*Van Ackeren, J.
*Vandevort, F. F.
*Vann, J. A.
Vant, George H.
*Van Vleck, W. H.
Velte, Ralph C.
Verity, George M.
Vincent, Joseph E., Jr.
Voigt, P. F.
*Vosburgh, F. J.
Vosmer, William F.
Vought, Charles S.
Vreeland, George W.

*Wadhams, A. J.
*Wagoner, A. L.
Wales, Quincy W.
Walker, W. R.
*Wallis, W. B.
*Walsh, Philip C., 3rd
Walters, F. W.
Ward, James H.
Ward, Thomas C.
Wardwell, A. H.
*Warley, H. W.
*Warren, A. C.
*Warren, James
Waterhouse, George B.
Waterman, Fred W.
Watson, R. H.
Watson, W. E.
*Way, S. A.
Wayland-Smith, Richard
*Wegener, E. R.
*Weiss, Frank A.
Welborn, J. F.
Welch, William W.
*Weldon, M. J.
*Welihan, R. J.
*Wells, T. R.
Westfall, Harry D.
Wetherell, L. H.
*Wetzel, John E.
Weymouth, Fred A.
Wheeldon, John
Wheeler, Seymour
*Whitaker, H. A.
*Whitaker, Nelson E.
*White, E. E.
White, G. Arthur
*White, H. A.
*White, H. E.
White, Joseph K.
*White, P. G.
*White, R. W.
*White, W. Foster
*Whitehead, J. J.
*Whitney, R. H.
*Whitson, S. W.
Whyte, George S.
*Wight, Henry A.

*Wilcox, Robert I.
Wiley, Brent
*Wiley, J. S.
Wilkinson, Horace S.
Willcox, Frederick H.
*Williams, B. P.
Williams, Edward H.
Williams, H. D.
Williams, J. C.
*Williams, J. P., Jr.
Williams, Leonard W.
Williams, Louis W.
*Williams, R. B.
*Wilson, George T.
Wilson, Parker F.
Wilson, Willard
Winckler, Elmer E.
Witherow, W. P.
*Wolcott, D. F.
*Wolcott, R. W.
Wolhaupter, Benjamin
Wood, Charles L.
Wood, Howard, Jr.
Wood, Richard G.
*Wood, Vincent P.
Woods, John E.
Woods, Leonard G
*Woodward, Stanley
*Wooldridge, C. L.
Worrilow, W. H.
Worth, Edward H.
Worth, William A.
Worth, W. P.
Wright, S. D.
Wright, William H.

Yeates, Frederick C.
*Yoder, J. O.
*Younglove, E. H.

*Zeller, F. B.
Zimmermann, R. E.

PARTICIPANTS—OCTOBER MEETING

(*Guests)

Abbe, Albert N.
*Abbott, W. B.
Abbott, W. H.
*Abel, A. E.
Adams, F.
Affelder, Louis J.
Agnew, J. C.
Agnew, J. D.
Ahlbrandt, George F.
*Ailes, E. R.
Akin, Thomas R.
Alderdice, George F.
*Alexander, C. W.
*Allderdice, Norman
Allderdice, Taylor
*Allen, A.
Allen, John N.
Allen, J. P.
Alley, James C.
Allyn, A. W.
*Amis, Frank W. T.
Anderson, Brooke
Anderson, C. A., Jr.
*Anderson, Geo. B., Jr.
*Anderson, J. N.
Anderson, Nils
Anderson, W. A.
*Andrews, Frederick
Andrews, J. B.
*Armstrong, Duane
*Armstrong, L. B.
Armstrong, Victor C.
Arnold, L. L.
*Arnold, R. H.
Arthur, T. A.
*Aspin, Robert
*Atkinson, Lloyd H.
Atwater, C. G.
*Aurelius, S. J.
*Austin, F. G.
Austin, H. L.
*Azar, J. A.

Baackes, Frank
*Bahr, H. T.
Baily, T. F.
*Bain, H. Foster
Baird, Frederick C.
*Baizley, John
Baker, Merrill G.
*Baker, P. R.
Bakewell, D. C.
Baldwin, C. Kemble
Baldwin, H. G.
Baldwin, R. L.
Balkwill, George W.
*Ball, L. C.
*Ball, Samuel
*Balliett, B. J.
Balsinger, W. R.
Baltzell, Will H.
*Bancker, W. F.
*Banks, Harold P.
Barashick, A.
*Barbour, A. W.
*Barbour, James W.
*Barnes, H. H., Jr.
*Barnum, J. P.
Barrows, W. A., Jr.
Barrows, W. A., 3d
*Bartlett, Lyman
*Batteiger, R. L.
*Baur, C. S.
*Baxton, J. W.
*Baylies, F. N.
Beach, F. W.
*Beal, A. G.
Beale, A. H.
Beale, H. A., Jr.
*Bean, Henry Willard
Beaver, H. C.
*Becher, Eugene
*Beck, Carl
*Beck, E. A.
Becker, Joseph
*Becker, Luther
*Becket, F. M.
*Beebe, F. H.
*Beegle, Clifford H.
Beegle, F. N.
*Belfield, H. B.
Bell, C. H.
Bell, Frank B.
Bell, G. Graham
*Bellville, H. C.
Bennett, C. W.
Bennett, David P.
Bennett, W. H.
Bent, Quincy
Bentley, Robert
*Beppeler, J. H.
*Berger, A. B.
Bergquist, J. G.
*Berton, E. D.
*Berton, Edmond D.
*Bialosky, I.
*Bickell, C. H.
Biggert, C. F.
Bigler, F. S.
Billard, J. D.
*Bingaman, R. W.
Birney, E. H.
*Bitting, William S.
*Black, J. B.
*Blair, R. F.
*Blendinger, F. L.
Block, L. E.
Block, P. D.
Blowers, William B.
*Boecker, O. F. G.
*Bolton, Julian C.
Bonner, James B.
*Bonny, Carl
Booth, Charles H.
Booth, Lloyd
*Booth, Thomas H.
Bothwell, W. J.
Bourne, H. K.
Boutwell, R. H.
Boutwell, R. M.
*Bower, W. C.
*Bowers, E. C.
*Boyd, James
Boyd, P. M.
Boyer, Pearce F.
*Boynton, H. C.
Bradley, Carl D.
Bradley, H. S.
Braid, Arthur F.
*Brandeis, Eugene
*Brantingham, Charles S.
Brassert, H. A.
*Briggs, Carl R.
Brion, A. E.
*Brion, Lester
Brokenshire, E. L.
*Brook, Frank W.
Brooks, C. K.
Brooks, J. J., Jr.
Brotherton, Fred C.
*Brower, Roy L.
*Brown, Archer H.
Brown, Charles M.
*Brown, E. W.
Brown, Frank L.
*Brown, H. B.

Brown, Lowell H.
*Brown, W. J.
Browne, de Courcy
Bruce, Robert A.
Brunke, F. C.
Brunner, John
Buck, C. A.
Buck, L. J.
*Bucommon, Emil
Budd, R. B.
Buell, J. A.
Buffington, E. J.
*Buick, James M.
Bull, R. A.
*Bunn, F. W.
*Bunting, Harry
Burden, James A.
*Burgers, Franz
Burt, D. A.
Burton, Carroll
Bush, D. Fairfax
Butler, Gilbert

*Caldwell, J. D.
*Callow, Will K.
*Campbell, Benjamin
Campbell, J. A.
Campbell, L. J.
*Campbell, W. A.
*Cannon, Russell A.
Carney, Frank D.
*Carpenter, W. T. C.
*Carr, Francis
*Carroll, C. S.
*Carroll, W. J.
Carruthers, J. G.
Carse, David B.
Carse, John B.
*Carse, John B.
Carson, George C., Jr.
Carson, Harry D.
*Carswell, J. B.
*Carter, C. H.
*Carter, Robert S.
Casey, J. S.
*Casey, F. Y.
Cebrat, Paul
*Chamberlain, Arthur H.
*Chambers, C. E.
*Chandler, Hal
*Chandler, Henry
*Chandler, W. P., Jr.
Chapin, F. H.
*Chapman, Edward J.
Chapman, Niles
Chapman, W. B.
Charls, George H.
Cherry, C. A.
*Childs, W. H.
*Chisholm, C. G.
Christ, E. W.
Christian, A. W.
Church, Edwin S.
Clarage, Arthur T.
Clark, Edward F.
Clark, Eugene B.
*Clark, J. I.
Clark, Ralph W.
Clarke, Charles E. F.
Clarke, E. A. S.
Clarke, N. J.
*Clements, B. A.
Clingerman, W. H.
Close, C. L.
Cluff, C. C.
Clyde, W. G.
*Coffey, M. J.
Coffin, William C.
Colladay, Frank H.
*Colling, A. F.
Collins, E. C.
*Collins, F. L.
*Condit, E. A., Jr.
*Cone, E. F.
Connell, F.
*Constock, John R.
Cook, Howard D.
Cook, Howard H.
*Cook, S. H.
Cooper, S. G.
Corbett, W. T.
Corey, A. A.
Cornelius, Henry R.
Cornelius, William A.
Cort, Stewart J.
*Cosgrove, William H.
*Costa, M. A. Martins
*Cotsifas, D. D.
Coulby, Harry
*Cowan, J. D.
Cox, Walter S.
Crabtree, Fred
*Craig, Horatio
Craig, Sam N.
*Crawford, C. J.
*Crawford, D. F.
*Crawford, H. C.
*Crawford, R. S.
*Creem, D. J.
Creighton, Louis E.
Crewe, L. C.
*Critchett, J. H.
Crocker, George A., Jr.
Crook, Alfred
Crosby, Fred B.
Crotsly, A. W.
Crowley, Dennis, Jr.
Croxton, D. T.
*Crusan, C. B.
*Cueman, J. Bently
Cummings, S. H.
*Curlburt, Isaac
*Curley, J. F.
Cushwa, C. B.
Custer, L. R.

Daft, Andrew C.
*Dailey, J. B.
Dalton, H. G.
Daly, J. P.
Damerel, George
*Dana, C. A.
*Dana, R. H.
Danford, M. E.
Danforth, A. E.
*Danforth, C. E.
*Danforth, Geo. L., Jr.
Davey, A. I.
Davey, W. H.
*Davies, A. P.
Davis, G. L. L.
*Davis, J. M.
Davis, S. A.
Davis, W. P.
Deericks, Joseph G.
Deming, Fred C.
*Dench, W. L.
*Denio, George L.
*Denman, L. E.
Desmond, John F.
Dette, William
Deutsch, Lee
Devens, Richard
*Deyer, R. G.
*Dice, A. T., Jr.
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Dickey, W. C.
Dickson, W. B.
*Diercks, Jules
*Dillon, James J.
*Dimm, I. L.
Dimmick, F. D.
Dinkey, A. C.
*Dirkes, F. A.
Ditto, M. W.
*Dixon, J. Shipley
*Dodson, R. I.
Donner, J. W.
Donner, Robert
Donner, W. H.
Dorman, A. D.
Dorman, P. O.
Dorsey, R. M.
*Dougherty, H. N.
Dougherty, J. W.
Dowling, Eugene
*Dowling, J. W.
*Down, H. G.
*Downey, A. C.
*Dressel, J. G.
Duane, James, Jr.
Du Bois, H. C.

*Duemler, Fred
Dunsford, J. R.

Eager, William H.
Easton, H. M.
Eaton, C. D.
Eaton, W.
*Edgerley, W. H.
Edwards, E. T.
Edwards, Gordon L.
Edwards, V. E.
*Ehrhardt, F. W.
Elkin, S. E.
*Elkin, W. S.
Ellicott, C. R.
Ellis, J. M.
*Emerson, Harrington
*Ennis, J. B.
Entwisle, E. B.
*Entwisle, E. F.
Eppelsheimer, Daniel
Epstein, Max
*Euler, Walter
*Eustace, J. H.
Evans, George D.
Everhart, W. H.
*Exstein, Henry L.
Eynon, D. L.

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*Fairless, B. F.
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*Faunce, B. F.
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*Feldmann, H. M.
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Field, H. E.
Filbert, W. J.
*Finch, J. H.
Findley, Alvin I.
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Fisher, P. L.
Fisher, William Garrow
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Fletcher, J. F.
Floersheim, Bert
*Foley, John
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Follansbee, William U.
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Forbes, W. A.
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*Forrest, Andrew
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*Foster, H. M.
*Foster, Paul F.
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Fowler, Oswald
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France, J. H.
*France, William A.
Francis, Lewis W.
Frank, Fritz J.
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Freyn, H. J.
*Fritz, Charles F.
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Froment, Eugene McK.
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Fuller, F. M.
*Fuller, H. H.

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Gathmann, Emil
*Gathmann, Mark
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*Germain, E. B.
Gerry, Roland
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*Gordon, Frederick S.
*Gordon, R. L.
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*Griffiths, R. E.
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*Hamilton, R. H.
Hancock, W. W.
Hanlon, W. W.
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Harrison, N. C.
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Henry, J. B.
Henshaw, J. O.

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*Hodges, C. W.
*Hodson, Frank
Hoerle, F. D.
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Holmes, C. O.
Holmes, George C.
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*Holmes, Joseph H.
*Hoot, J. C.
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*Kimball, George T.
*Kimball, W. A.
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*Klein, L. C.
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*Knapp, W. J.
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Lewis, H. E.
*Lewis, H. S.
Lewis, John F.
*Lindemuth, F. L.
Lindemuth, L. B.
Linney, J. R.
Linton, Robert
Lippincott, James
Lissberger, B.
*Lissberger, E.
*Lissberger, M.
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Logan, John W.
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Longacre, John A.
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Lovejoy, Frederick B.
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*Lovett, H. D. B.
*Lowe, L. J.
Lowell, George C.
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Lucas, George C.
Lukens, W. W.
Lundie, John
*Lupton, Edward
Lusk, Rollin W.
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Lyman, Frank
*Lynch, Henry H.
*Lynch, T. J.

*MacArthur, Angus
*MacArthur, D.
MacCleary, W. M.
*MacGregor, Peter
MacMurray, James E.
MacQuigg, C. E.
McAlarney, J. H.
McCaffrey, Thomas
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McCleary, E. T.
*McClintic, H. H.
McConnell, John
*McCurrach, J.
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McDonald, Louis N.
McDonald, Thomas
McDonnell, E. J.
McDougall, D. H.
McElwain, John
McFarland, A. J.
McFate, Wlliam M.
McGee. Harry L.
McGrady, J. W.
McIlravy, W. N.
*McKee, John K.
McKee, W. S.
McKenna, Roy C.
McKillips, Charles E.
*McKillips, J. F.
McKinney, Price
*McLeod, S. V.
McManus, P. F.
McMaster, R. H.
*McMillen, W. W.
*McNamara, J. F.
*McNiff, G. P.
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Mace, A. W.
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*Maguire, Walter P.
*Maher, J.
*Mahl, F. W.
*Malmstrom, U.
*Maloney, J. E.
Mann, Albert C.
*Mansfield, Edwin
Manville, Tracy F.
Marchant, C. R.
*Marchant, R. B.
*Markey, J. J.
*Marran, V. P.
Marshall, C. D.
*Marshall, D. J.
Marshall, S. M.
*Martin, W. N.
*Martini, Wilhelm
Mason, George A.
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*Mason, Ralph
*Maste son, Edward J.
*Matchett, Thomas
*Mather, Gordon M.
Mather, Samuel
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Mathews, John A.
*Maxwell, Allison R.
*Mayer, Peter C.
Meacham, Standish
*Mead, A. B.
*Meanley, M. B.
Meissner, Carl A.
*Meissner, Clarence E.
*Meissner, C. R.
*Meissner, Harold G.
*Menefee, Arthur B.
*Mercer, C. Douglas
Mercur, R. J.
*Merrill, C. A.
Mesta, George
Metcalf, Morris
Meyer, A. L.
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Miller, C. L.
*Miller, F. C.
*Miller, J. A., Jr.
*Miller, L. H.
Miller, Louis H.
Mills, Edwin S.
Mills, James R.
*Minich, Verne E.
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*Mitchell, Chas. S.
Moffett, C. A.
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Moore, E. A.
Moore, Frank
Moore, H. G.
*Moore, H. K.
Moore, Philip W.
*Moran, E. F.
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Moreland, W. C.
Morgan, W. H.
Morris, A. F.
Morris, G. B.
Morris, H. T.
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*Morris, R. H.
Morris, William J.
*Morrison, John H.
*Morrow, Dwight M.
Morrow, Hugh
Morse, A. C.
*Morse, Perley
*Mossman, P. B.
*Moyer, L. M.
Moynes, K. W.
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Mueller, O.
*Mullen, Edgar
Mulligan, John
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*Murray, Andrew B.

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*Newlands, Harrod C.
*Newman, R. K.
Newton, H. B.

Nicholas, Richmond
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Nields, Benjamin, Jr.
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*Nivison, R. E.
*Norris, F. P.
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Norton, Frank L.
*Norton, R. H.

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*O'Connell, W. L.
Ogden, F. A.
Olcott, W. J.
*Olfe, Hermann
Oliver, Henry
Oliver, W. H.
*O'Neil, F. Edward
*O'Neil, F. W.
*Opderbeck, Emil
*Orr, Charles T.
Orrock, George A.
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*Overton, C. I.

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*Parker, J. A.
Pattison, Melvin
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*Pease, M. H.
Peck, Claude J.
Peck, H. H.
Peckitt, Leonard
Pendleton, John S.
*Perkins, Wallace T.
Perry, J. E.
Peters, Richard, Jr.
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Petinot, N.
Pettis, Clifton D.
*Pettis, William M.
Pfeiff, L.
*Pfitsch, Charles G. A.
*Pfitsch, Karl G.
Pflager, H. M.
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Phillips, W. Vernon
*Pierce, Clifford E.
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Pilling, William S.
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Pond, Clarke P.
Pope, H. F.
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*Porter, Ralph W.
*Pouch, W. H.
*Poucher, R. I.
*Prenosil, S. W.
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*Rhodes, Frederick H.
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Richards, F. B.
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Robinson, T. W.
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Ruder, W. E.
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Rust, W. F.
Rys, C. F. W.

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Sawyer, D. E.
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*Siebert, George E.
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*Sloane, W. D.
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*Smith, David H.
*Smith, Dudley J.
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Smith, Lewis R.
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Smith, S. L.
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Solomon, Max
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*Sproul, John R.
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*Starr, George W.
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Steif, Erwin A.
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Steuer, L. R.
*Steven, Frank R.
Stevens, H. L.
*Stevens, R. H.
Stevenson, A. A.
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Stewart, Scott
Stillman, Charles A.
Stillman, J. S.
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*Stoll, H. E.
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*Stone, Junius H.
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Taylor, Wade A.
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Touceda, Enrique
Towne, Thomas
Townsend, A. J.
Townsend, H. E.
Townsend, J. Fred
Transue, O. F.
Tredennick, H. L.
*Treharne, E. B.
Trinks, Willibald
Tripp, Chester D.
*Troth, A. D.
*Tucker, John O.
Turner, V. C.
Tutein, Dexter A.
Tutein, E. Arthur

Uphouse, H. G.
Utley, S. W.

*Van Ackeren, Joseph
*Van Cott, Lincoln
*Vandevort, F. F.
*Van Gunten, Charles
*Van Horn
Vant, George H.
Velte, Ralph C.
Vincent, Joseph E., Jr.
*Vogelgesang, Rear-Admiral, C. T.
Voigt, Paul F., Jr.
*Vosburgh, F. J.
Vosmer, W. F.
Vought, Charles S.
Vreeland, George W.

Waddell, Jacob D.
Wade, Fred. A.
*Wagner, E. J.
*Wagoner, A. L.
Wales, Q. W.
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Walters, F. W.
*Walters, George
Ward, J. H.
*Ward, Stevenson E.
Ward, T. C.
Wardwell, H. F.
*Warley, H. W.
Waterhouse, G. B.
Waterman, F. M.
Waterman, F. W.
Watson, J. J.
Watson, Walter E.
Wayland-Smith, R.
*Weaver, H. B.
*Weed, R. S.
*Wegener, E. R.
Weir, E. T.
*Weiss, F. A.
Weiss, J. G.
*Weldon, M. J.
Wendell, Carl A.
Westfall, Harry D.
Weston, W. B.
*Wetherby, J. L.
Wetherell, L. H.

*Wetherill, Samuel
Weymouth, F. A.
Wharton, Clifton, Jr.
Wh eldon, John
*Wh taker, H. A.
*White, C. S.
*White, H. E.
White, Herbert
*White, Hubert A.
*White, R. W.
Wh tehead, G. W.
*Whitehead, J. B.
*Whitman, Russell R.
*Whitney, R. H.
Whittemore, E. L.
Whyte, George S.
Wickwire, T. H., Jr.
*Wight, S. B.
Wiley, Brent
Wilkin, John T.
Wilkinson, H. S.
Willcox, F. H.
Wille, F.
*Williams, B. P.
*Williams, C. H.
Williams, E. H.
*Williams, George C. F.
Williams, H. D.
Williams, Louis W.
*Williams, R. B.
*Williams, S. D.
*Willing, George, Jr.
Wilson, P. F.
Wilson, Willard
Winckler, E. E.
Winkler, L. H.
*Winter, Emil
Wisener, G. E.
Wolhaupter, Benjamin
Wood, Charles L.
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Wood, Howard, Jr.
Wood, R. G., Jr.
*Wood, Vincent P.
Wood, Walter W.
Woods, John E.
Woods, L. G.
*Woodward, Stanley
Wooldridge, William J
Worrilow, W. H.
Worth, E. H.
Worth, W. A.
Worton, Samuel G.
*Wright, C. E.
*Wright, J. D.

Yeates, F. C.
*Yoder, J. O.
*Young, C. D.
Young, F. C.
*Younglove, E. H.

Zeller, H. P.
Zimmerman, R. E.

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